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BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE

No. 115

Contribution from the Office of Experiment Stations, A. C. True, Director.
September 1, 1914.

(PROFESSIONAL PAPER.)

GATE STRUCTURES FOR IRRIGATION CANALS.

By Fred C. Scobey,
Irrigation Engineer, Irrigation Investigations.

INTRODUCTION.

A study of the irrigated regions of the West shows that the designs and special features of structures have been copied and adapted one from another, but usually within the bounds of one locality. Two sections with quite similar conditions show great divergencies in structures used for the same purposes. This is true largely for the reason that those who design the structures have neither the time nor the means to travel and learn how others are handling similar situations. The purpose of this bulletin is to bring together designs adapted to many localities, in order that the practice of the whole country may be available to those who design structures.

The purpose of all gates considered in this bulletin is the control of the flow of water in ditches or canal systems. Headgates and floodgates regulate the water entering the system from the source of supply; check gates regulate the water while within the canal; sand and waste gates control the water which is to be turned out and wasted; and branch canal, lateral, and delivery gates regulate the water turned out to branches of the system or to users. Bifurcation works and division gates usually serve the combined purposes of check gates and branch canal or lateral gates, and are used to regulate the flow of water in the main canal and also of that passing into branches or laterals.

For the most part small and medium-size structures are dealt with, as it is believed that most of the problems confronting the engineer located in isolated parts of the West relate to structures of this class. The bulletin should also be of value to directors of mutual water companies, who are themselves irrigators and who are called upon to pass on questions of construction and maintenance.

Note.—This paper will be of interest to engineers and directors of farmers' canal companies in the irrigated sections of the West.

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Since the bulletin is prepared for engineers and others who are familiar with gates and gate structures, it does not attempt to treat the subject fully, but merely gives examples of structures which serve the purpose for which they are intended better than many others in common use. Local conditions control many features of gate structures, and the descriptions given relate to existing structures in actual use, which it is believed will prove suggestive and can be readily adapted to other conditions by local engineers and ditch owners.

MATERIALS USED.

A few years ago most of the structures in American canals were of wood, but more recently concrete, both plain and reinforced, has come into common use. Wood has the advantages of cheapness and ease of handling and the disadvantage of rapid depreciation. Concrete has the advantage of permanence, but is costly. In determining which to use, these points must be taken into consideration. The most prominent facts in connection with recent irrigation development under both public and private agencies have been the high cost of water rights and the inability of settlers to make the payments required. In view of these facts there is much to be said in favor of the cheaper wooden structures for original construction with a view to their replacement with more permanent structures of concrete as the wood decays. This will lessen first cost and bring the heavier cost after the lands have been put under cultivation and the expenses incident to the establishment of new farms have been met. The use of wood has the further advantage that any mistakes in either the type of structures or their location are not so costly. It frequently happens that structures are found to be placed too high or too low, or to be too small or not of the best type for the purpose to be served. A few years' experience in their operation will demonstrate these facts, after which permanent structures may be put in with an assurance that they are what is needed.

Another condition to be taken into consideration in determining the material to be used for structures is the damage which is likely to be done in case of failure. If the failure of a structure will result in great damage to the canal system, or to crops or other property below, only the most nearly permanent construction should be used. If, on the other hand, failure will mean merely the replacement of the structure itself, cheaper construction may be used.

Probably the best practice is to make combined wood and concrete structures, using concrete for the parts which are inaccessible and not easily replaced and wood for the accessible parts which can be replaced easily. Local conditions affecting the relative prices of wood and concrete will also help to determine which material should be used.

TYPES OF GATE SHUTTERS.

The openings or vents in gate structures generally are regulated by either slot shutters, comprising flashboards and wooden and metal slide gates; radial gates; or shear gates. There are also several styles of collapsible gates, roller curtains, needles, butterfly gates, and other devices, but their use is very limited in this country, and for that reason they are omitted from this publication.

SLOT SHUTTERS.

The type of slot shutters in most common use is a wood or metal shutter sliding in grooves or slots. This arrangement does very well for small gates, but where the opening is so large that there is any great amount of pressure against the gate the friction becomes so great as to render the operation of the shutter difficult. Sometimes this sliding friction is reduced by inserting a roller bearing between the shutter and the guide.

Wooden gate shutters are the most common of all types. Various types of wooden shutters are shown in Plate I. Slides for openings up to about 4 feet wide are made wholly of wood, as a rule. Larger shutters are usually braced with iron, and those 8 to 12 feet in width commonly are furnished with a metal shoe which slides against the guide. Small gates are usually nailed together, but it is better to use bolts freely on gates wider than 3 feet.

If redwood lumber is used gates up to 3 feet wide may be made of 1-inch stuff single thickness, but above that it is recommended that at least 2-inch stuff be used, or, better still, double 1 or 1½ inch, with the two layers at right angles to each other. Tightness may be secured by placing a layer of tar paper between the two layers of wood. Gates of pine and of any timber other than redwood, except very small ones, should not be made less than 2 inches in thickness. If built of double material they will be more nearly water-tight and stiffer than if built of a single thickness.

Most of the much-used metal slide gates are made by foundries and machine shops that specialize in this work and issue very complete catalogues that describe in detail each kind of gate. Most of them are included in one of three types: Gates for pipe deliveries through the banks, gates for rectangular tubes of wood or masonry through the banks, or gates for open channels. The first type consists of a sheet-steel or cast-iron slide over a cast-iron face orifice with angle iron or steel standards and the necessary lugs to attach the gate to the bell, and of a cast-iron, vitrified-clay, cement, or corrugated-iron pipe. In the trade nomenclature the size of the gate agrees with the size of the pipe to which the gate is to be attached; that is, an 8-inch gate is ordered to fit a pipe 8 inches inside diameter.

Practically all gates of this type are fitted with screw and wheel lift and locking devices. The locking device usually consists of some form of cast-iron nut turning on the thread of the gate stem under the crosshead. As the stem does not turn around but is lifted simply by the threads in the wheel it is necessary only to screw the loose nut to any desired point and lock it to a chain or bar connecting with one standard. This prevents it being turned in either direction, and when the stem is raised until the nut reaches the crosshead, the shutter is locked as regards further opening, but may be closed partially or wholly by the consumer. Other devices used lock the gate so that it can not be either opened or closed except under action of the key. (See fig. 11, p. 42.)

Most of the standards of this type of gate come in lengths of 6 feet unless ordered otherwise, but the writer noticed many cases throughout the West where a material saving could have been exercised by ordering shorter lengths of standard.

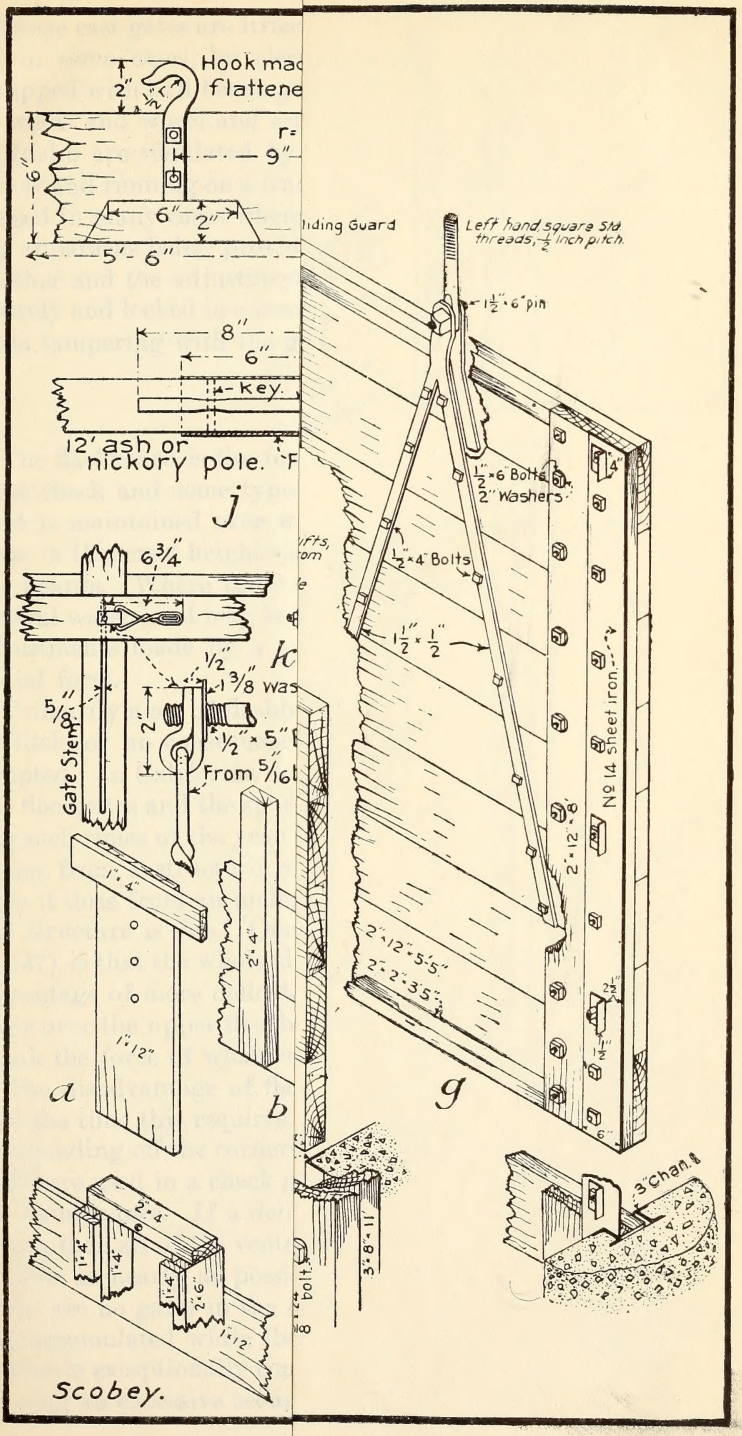
The standards may be made so that they will be at right angles to the connection for the pipe or at an angle of 60° or 75° with the pipe. In most cases the 75° angle probably will give better results, as the face then will be more nearly in conformity with the slope of the bank. One manufacturer even makes a type with a slope of 45° with the pipe.

Most makers step up the gate sizes to conform to the sizes of standard vitrified-clay pipe beginning at 6 inches and going to 24 inches. Some makers have gates for 30 and 36 inch pipe, but as a rule the type is changed.

Gates with connections for rectangular openings are for use with timber or masonry tubes larger than standard sizes of pipes, as a rule. The standards, locking devices, etc., are the same as on the gates for pipes. These gates run in various sizes from 6 by 6 inches up to several feet in either dimension. The stems and lifts vary all the way from a simple handle and bar up to powerful geared rack-and-pinion or screw lifts.

The third type of gates consists of sheet-steel or cast-iron slides with metal guides. They come in sizes up to about 12 feet wide and may be built up from a single panel to a battery of several openings. Where the masonry structure is divided into vents by masonry piers each gate is a unit independent of the others. They also are designed in batteries for installation as a metal unit in a gate structure with walls and floor of concrete or rubble masonry. This class has a structural steel frame securely anchored by bolts to the floor and walls. An example of this type of gate is shown in Plate V, figure 2.

The rack-and-pinion lift is the most common type for this class of gates. On the more simple ones the lever acts directly on the pinion, the gate being held by a pawl. More power is secured by inserting a train of gears between the lever and the rack.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key.
12' ash or
hickory pole.
j
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6¾"
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1⅜" was
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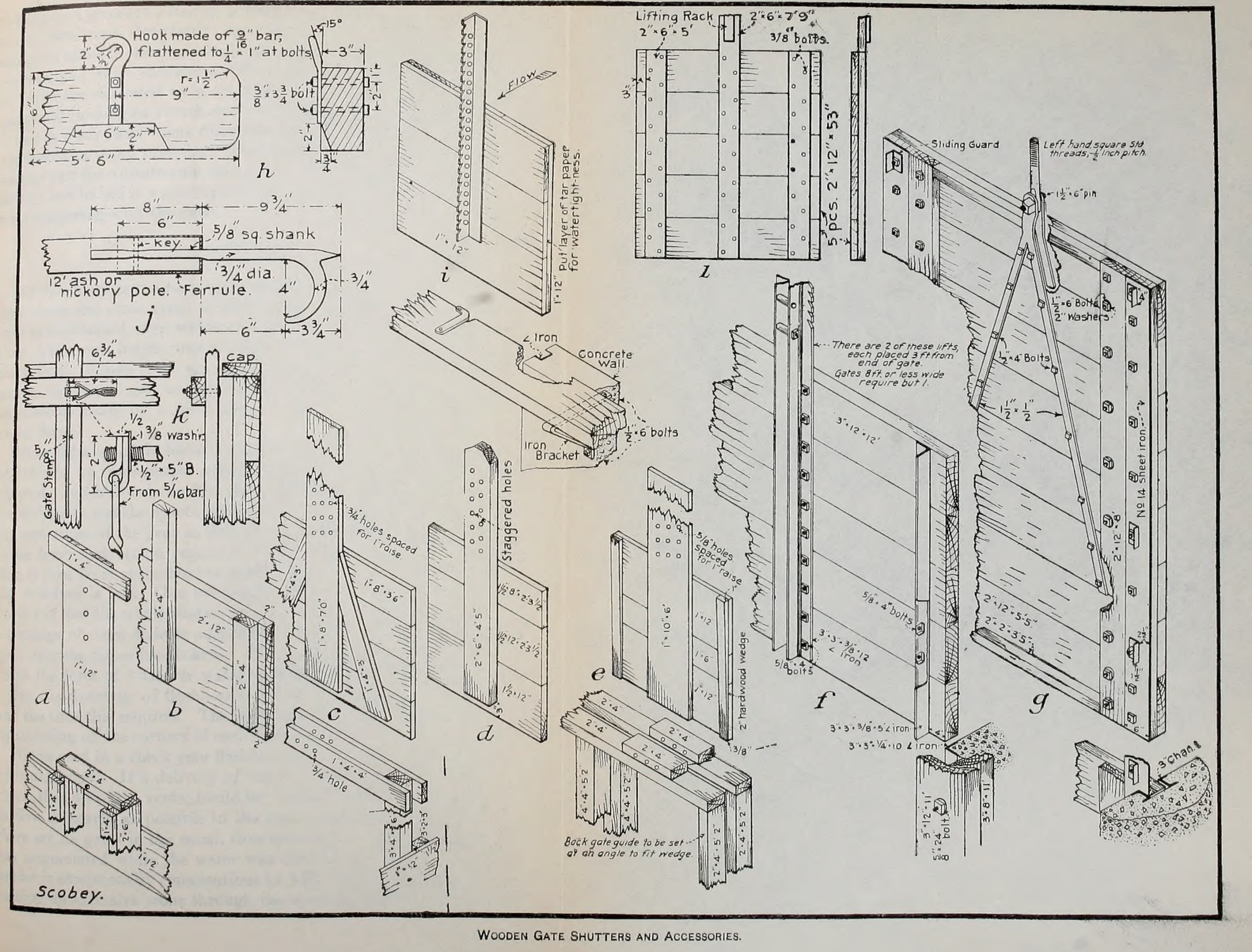
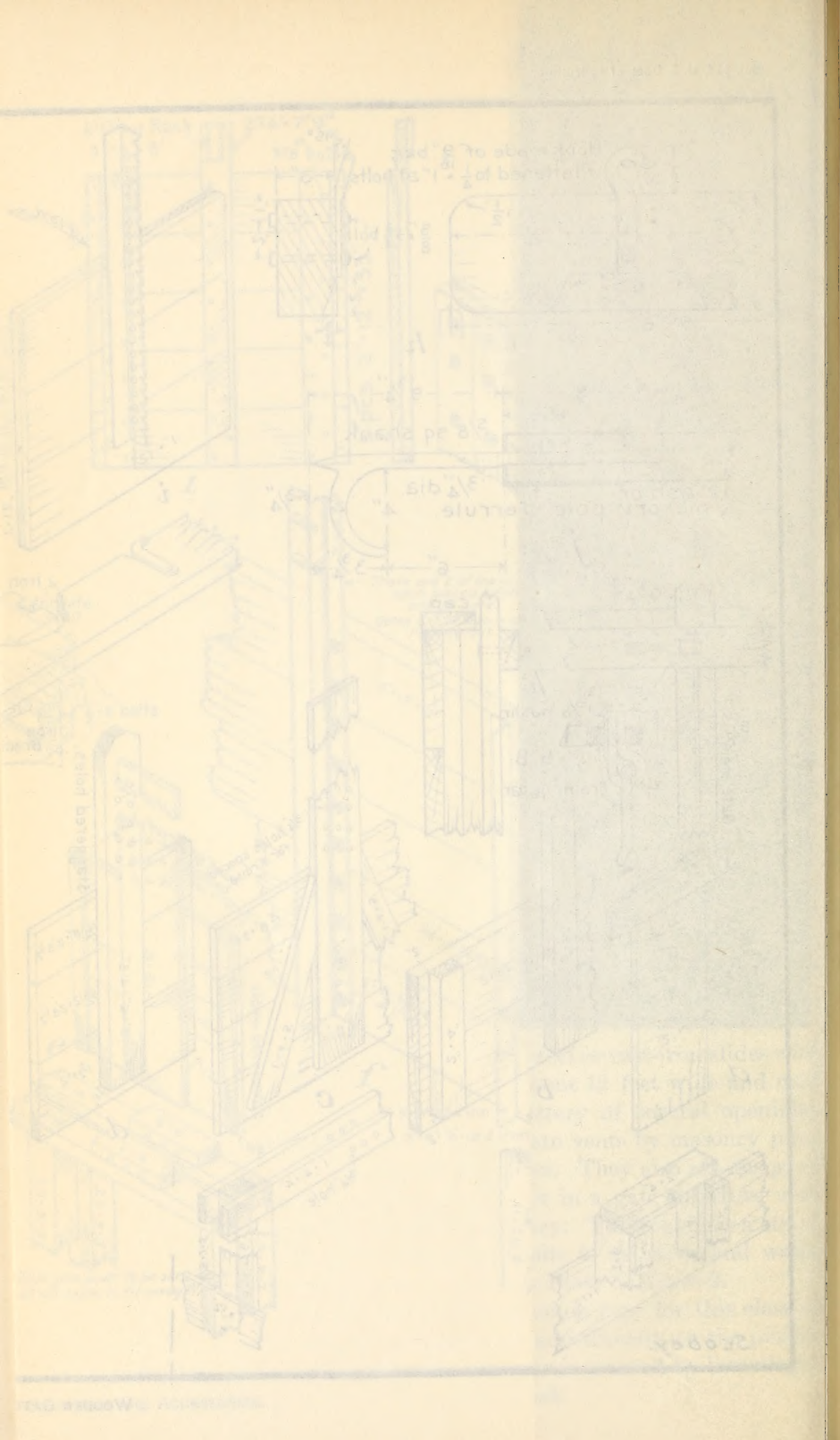


WOODEN GATE SHUTTERS AND ACCESSORIES.



Large cast gates are lifted by powerful one or two man gate stands, or, in some cases, by electric or water power. These stands are equipped with ball-bearing wheel and screw, bevel gearing and screw, or worm and wheel and screw. The waste gates on the Milner dam in Idaho are regulated by a traveling hoist equipped with electric power and running on a track set back of the gate guides. This device is used in many cases where there is a battery of gates, but one hoisting apparatus being provided. This is transferred from one stem to another and the adjustments made. The hoist may then be removed entirely and locked in a near-by tool house, thus preventing passers-by from tampering with the gates.

FLASHBOARDS.

The flashboard is the form most used for an overflow gate, such as most check and some types of waste gates. With boards a definite crest is maintained over which any excess water will pass. Alterations in this crest height may be made in steps gaged by the width of the boards. Where there are several panels in a gate structure the general water level may be regulated by flashboards and more delicate adjustments made by a solid gate shutter of either the groove or radial form.

Primarily a set of flashboards should be used only where leakage is of little or no consequence unless measures to prevent leakage are adopted. In California double sets of flashboards sometimes are used for floodgates and the spaces between them are packed with mud during such times of the year as they are not being adjusted. The water issues from a structure regulated by flashboards with less velocity than it does from an undershot gate, and the resulting erosion below the structure is less. One advantage of the type shown in figure 8 (p. 37) is that the whole shutter may be lifted by the stem, giving the advantage of more delicate adjustment and still allow some water to pour over the upper flashboards. This water will fall on and tend to break the force of whatever water is passing under the gate.

The disadvantage of flashboards lies in the difficulty of operation and the time this requires. The jamming of a board may be reduced by rounding off the corners of each board as shown in Plate I, *h*.

Where used in a check gate flashboards develop a very bad feature of maintenance. If a delivery of water is not being made above the check, then all of the vents should be " pulled " and the water allowed to flow as nearly as possible in the same manner that it does when there are no gates in the canal, thus scouring out any deposit which has accumulated while the water was checked up. Unless the ditch tender is exceptionally conscientious he will " pull " one or two vents, causing an excessive scour through the openings pulled, and leaving

the silt deposit above the others. Of course this same condition must be guarded against where other forms of shutter are used, but it is much easier to pull all vents, if it can be done at one operation for each opening, than to fish out one flashboard at a time, with perhaps 8 or 10 boards in each vent.

This objection does not apply where boards are used to establish the crest of such a structure as a waste gate, designed for practically all of the water above the level of the crest to pass off and leave the canal. The water in the canal continually scours past the waste gate, keeping out the silt, and, as a rule, there are not many adjustments on such a gate throughout the irrigation season, there being a very material saving in the cost of gate lifts, which would be used only a few times in the season.

If flashboards are made loose enough so that they will operate with comparative ease, then there also is danger that they will float if the slots are made vertical. If the slots are inclined, the friction against the upper side of the slot counteracts the floating action of the water. Inclined slots also place the shutter so as to carry the thrust of water downward through the floor of the structure rather than tend to overturn it. The inclined slot requires more material for a shutter of a given height than does a vertical slot. Flashboards in an inclined set of slots can be more easily made water-tight by packing with mud than those in vertical slots.

SHEAR GATES.

During the past few years the shear gate has come into use on irrigation systems. It consists of a round cast disk turning on a pin through a hole at the edge of the disk. At the side opposite the pin is attached an iron rod for a handle. When the gate is closed the disk covers the end of a tube which is cemented to a cast-iron orifice plate. By means of the rod the disk is turned on the pin until the desired amount of water is delivered through the opening made as the end of the pipe is uncovered. In closing, the disk drops down between wedging lugs which bind the disk tightly to the face plate, making a comparatively water-tight connection. This gate costs but a fraction of the amount necessary for a metal slide gate, and could have been used in many cases where a slide gate has been installed.

To provide a locking device for this type of gate, the iron handle bar may be flattened and bored with slots to pass like a hasp over a staple set in the wall of the gate structure. The bar then may be slipped over the staple at the notch nearest the desired position and a padlock put through the staple.

RADIAL GATES.

The use of the radial gate is comparatively new in this country. It is essentially a gate raised and lowered by revolving on a horizontal

axle, to which the face is attached by arms centering at the axle. (Pl. II, fig. 1.) In practice the face of the gates has been made of simple planking nailed or bolted to ribs, or of sheet steel riveted to metal ribs. There have been a few cases where the face was built of reinforced concrete. In Canada a very simple type of this shutter has a perfectly flat face of planks attached to wooden arms. The practice in this country is for the face to form the segment of a cylinder. The arms of small gates may be made of wood, but the usual practice is to make the arms of angle or channel iron, even where the face is wood. The axles may be either sections of pipe or bars extending completely across the openings, or pins extending through the side walls adjoining the openings. Simple galvanized pipe makes a good axle for economical construction if the conditions at the gate structure are such that there is no danger of débris catching on the axle and bending it or washing it out. The more finished construction, which does not tend to obstruct the channel, consists of a steel pin set in a tube cast in the wall of the structure.

There are two great advantages in this type of shutter. First, friction is changed from sliding friction in the guideways, as usually used for gate shutters, to axle friction, with a lever arm the length of the gate arms. The second feature in favor of this gate lies in the form of lift. The usual stem-gate lift requires that the point of application be approximately twice the height of the opening above the bottom of the gate in order to lift the shutter clear of the opening. In nearly every case there is a waste of material in securing the elevation for the lift. This argument does not apply to most river gates, for the reason that the additional elevation is of benefit and is necessary in some form to give a high bulkhead to prevent flood water in the stream topping and destroying the structure. But there is an advantage in the case of other gates where the height of the levee is the controlling factor, and all the material above that height is so much that does not add any benefits to the structure. Since the cable or other form of lift can be attached to the very bottom of the radial gate, the winch may be set approximately on the level of the gate top when the latter is closed and the cable wound up by the winch, lifting the radial gate until the bottom is approximately level with the drum. As the radial gate requires no guides, it extends up into the air without other support than the axle, and there is no loss of material for lift standards, as is the case for most stem lifts.

The great factor against the radial gate always has been that the only discharge through it was undershot, but there is no reason why this should be, as the face does not need to be a single unit. It may be made of two or more sections, the upper ones hinging on axles car-

ried by the radial arms of the lower section or all centering on a common axle. With this arrangement water may be taken under, over, or between sections of the shutter. This allows heavy silted water to be held back in the stream and the lighter waters taken over the top of one or more sections of the shutter. The sectional construction also allows the upper sections to be lifted out of the way, so that the lower section may be partly raised and still have a low upper crest. This may be used as a wasteway to prevent floods from topping the levees. The ordinary radial-gate panels are closed at the top when the shutter is partly raised. The greatest use for this modification of the old radial gate is probably in river gates for canals and in crest gates regulating the water above a diverting weir. The solid type of radial gate probably will remain standard as a gate for a sand sluice where the scour at the bottom is necessary, and for all other gates than the river gates the character of the water and the manner of discharge will dictate the desirability of using the sectional type.

Very large openings probably are more easily regulated by the radial gates than by any other form of shutter used in this country at present, and for this reason they lend themselves readily to places where the openings must pass cakes of ice or small débris. On the other hand, large pieces of driftwood are a continual source of annoyance during flood times. This is true especially where the water is carried through submerged orifices, as the arms of the gate in such a case are within reach of the driftwood, which easily clogs in the irons of the gate.

If it is desired that a radial gate be made comparatively watertight, a strip of rubber belting on each side and at the top may be used. The bottom of the gate may close on a strip of wood set in the concrete floor, or it may close behind a shoulder of wood or concrete.

There are various ways of balancing a gate of this type so that the net amount of labor necessary to raise it may be reduced, although it is desirable that there be plenty of weight in favor of the gate in order that it may close of its own weight, as a cable or chain, the usual type of lift, can not be used to push the gate down as can a wooden or iron stem.

Since the pressure on the face of the gate is normal to the surface, then, if the face is a true segment of a cylinder, with the axle at the center, the pressure is transmitted directly to the axle, but if the axle is set below the center there will be developed a pressure passing over the axle and tending to raise the gate. This same effect may be obtained by spiraling the face of the gate so that the resultant pressure passes above the axle.

FIG. 1.—RADIAL GATE WITH CONCRETE COUNTERWEIGHT. LOWER END OF INLET TUNNEL, TURLOCK IRRIGATION DISTRICT, CALIFORNIA.

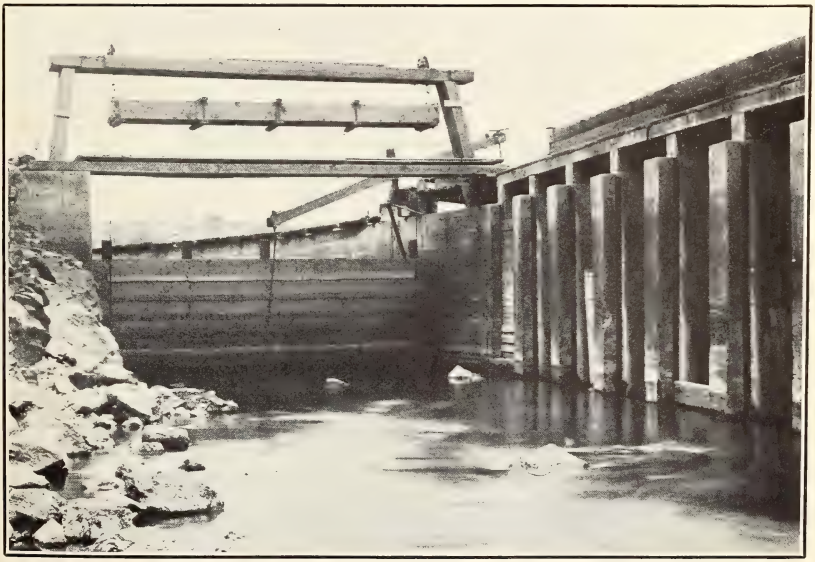


FIG. 2.—AUTOMATIC RADIAL REGULATOR GATE WITH SINGLE LEVER TO MAINTAIN CONSTANT VOLUME BELOW GATE. AT THE RIGHT FLASHBOARD WASTEWAY INTO TUOLUMNE RIVER, TURLOCK IRRIGATION DISTRICT, CALIFORNIA.

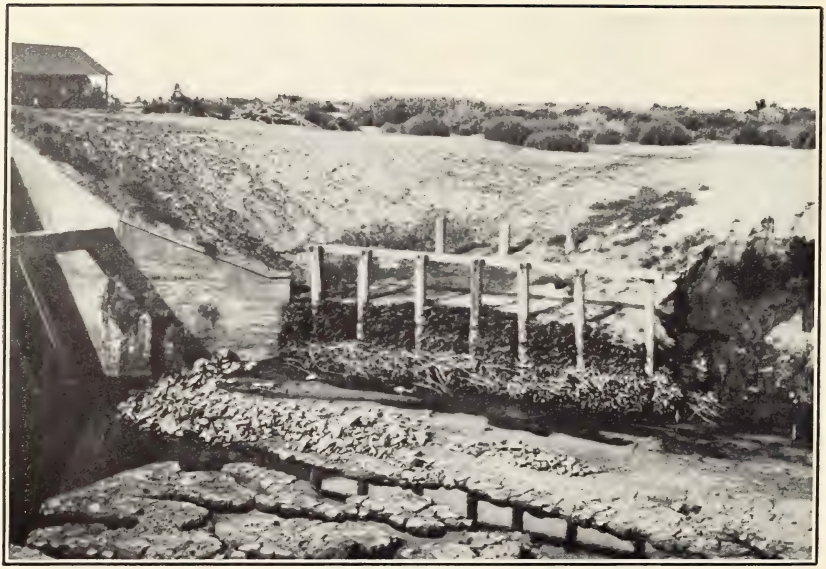


FIG. 1.—BRUSH RIPRAP BELOW ROSITAS WASTEWAY, CALIFORNIA DEVELOPMENT CO., CALIFORNIA.

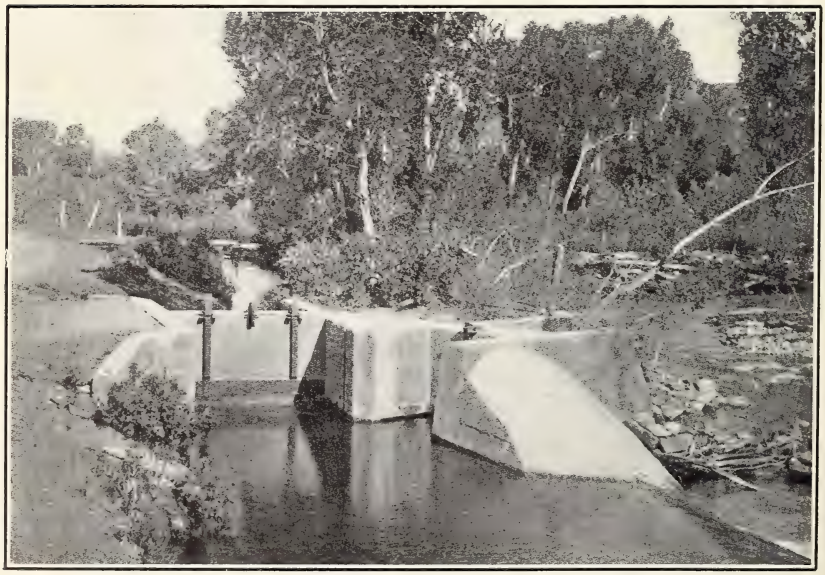


FIG. 2.—DIVERSION WEIR, SAND GATE, AND HEADGATE OF THE JACKSON DITCH NEAR FORT COLLINS, COLO.

GATE STEMS AND LIFTING DEVICES.

For very small gates using wooden shutters, the simple stem with staggered holes is recommended. (See Pl. I, *c*, *d*, *e*.)

For small iron shutters and wooden shutters up to 5 feet wide and 5 feet high a screw stem and wheel lift are recommended, for the reasons that they permit of adjustment to any desired point and are not controlled by the position of holes, notches, or other stepped devices (Pl. I, *g*). They exert a steady and gradual pull on the shutter, and do not jerk the gate to pieces. They may be used to force the shutter down as well as up, but it is recommended that they be placed in a pipe to prevent buckling if they are longer than twice the height of the shutter. The disadvantages are that the threads become bruised and corroded; that a screw can not jerk the gate where silt piles up against it when closed temporarily; that they are slow for large gates; and that the usual position is such that they require great physical effort to start and operate as compared with long-lever lifts, where a man simply may hang his weight on the end of the lever rather than use muscular force in turning the wheel.

For large sliding wooden gates a double stem with lever lift is recommended wherever they are known. The general construction of this type is shown in Plate I, *f*. This type is especially adapted to situations where a jerk may be necessary to start a gate. The lever may be used to force the gate either up or down. The disadvantages mentioned, which can be corrected easily, are that the stem crowds away from the fulcrum under the action of the lever; that a pawl is not reliable in holding the gate up; and that the lever is easily lost. By simply running the stem through a cast frame with a roller behind the stem, the latter may be held firmly up to the fulcrum. An even simpler method is to bolt a heavy timber to the head beam with a space for the stem between the timbers, as shown in Plate VI, figure 2. The pawl is used in the Arkansas Valley to hold this type of lift, and seems to give satisfaction. The lever may be chained to the structure. The double-stem lift does not have any complicated unit in its makeup, and all the necessary parts that go into the construction can be purchased at any hardware store. For this reason a broken piece can be replaced in a short time. A winch is recommended as a powerful hoist, but the great disadvantage is that it exerts tension only on the cable and can not be used to force down a gate. This practically precludes its use for any type but the radial gate, which has so little friction that it will close of its own weight where hung true and settling does not occur.

The rack-and-pinion lift is used a great deal throughout northern Colorado for gates of all sizes except the very smallest delivery gates.

It is fast, permits accurate and close adjustment, and the position of the lever operating the pinion permits a man to use his weight rather than his strength in adjusting the gate. The main disadvantage occurs in case of a broken casting, as no makeshift can be substituted easily, and the gate may be out of use until a new casting can be secured. This is one of the types of gate stem held by a pawl, and as such is criticized for the reason that the space between the notches controls the steps between the possible positions of the shutter.

As to the comparative advantages of wood, cast-iron, and sheet-steel gates, wood, of course, is the cheapest in first cost. It may be cut and adjusted easily to suit a gate structure that has settled or otherwise gotten out of line; it is elastic and will yield to prying where a cast gate will break. Ice does not freeze as tightly to wood as it does to iron or steel. On the other hand, the life of a timber shutter is much less than that of a metal gate and, as ordinarily constructed, it is less water-tight. Ice bulges wooden gates out of shape and will spring a sheet-steel shutter, but the latter can be pounded back into shape. A cast gate neither bulges nor springs but simply breaks.

Cast and sheet-metal gates cost more in the first place, but last a lifetime unless broken. Silt does not stick tightly to metal, especially a smooth, vertical side of sheet metal; such gates are practically water-tight, present a better appearance, and for this reason add to the project from a land-selling standpoint. The disadvantages are that they are liable to rust shut and break unless faced with brass. When they break the repair must come from a distance, taking time and money, while wooden gates can be repaired on the ground with lumber that can be obtained at any town. A cast gate is more easily broken by the action of a crowbar on a stuck gate or by a log in the stream than is either a sheet metal or a wood shutter.

PAVING AND RIPRAP.

The channel immediately above large gate structures may be eroded by the action of racing water, while new banks below nearly all structures become badly washed by the eddies of the issuing stream. The entry channel may be protected by a lining of concrete 3 to 6 inches thick or by a riprap of hand-laid bowlders or broken stone. This is sometimes grouted with cement mortar, forming a comparatively smooth, solid surface.

The erosion below a structure is far more difficult to handle than that above it and is more liable to cause the failure of the structure unless watched and checked in time. A short, smooth lining is only partially successful, as the high velocity in the water is not materially diminished and the erosion is only postponed until the water

reaches the end of the lined section, sometimes as far as 100 feet below a gate.

Canals near mountain streams having a bottom paving of bowlders may be protected by the liberal use of these bowlders laid as simple riprap or formed into rubble concrete paving by the use of cement mortar. A rough surface, gradually becoming about as smooth as the earth channel below it, will aid the water to secure its "balance" and to pass quietly into the unlined section.

In parts of the West far removed from bowlders in quantity but near sage-covered lands, this protection is secured by the use of bundles of sagebrush securely wired to posts driven deep into the canal bottom, while the California Development Co., in the Imperial Valley, has made a remarkably efficient riprap of greasewood. Where greasewood is scarce this company uses arrow weed or young willows, but these are not as durable as the greasewood. A structure protected in this manner is shown in Plate III, figure 1. The general procedure is as follows: The erosion of the bank below the gate is allowed to proceed, but carefully watched by the ditch tenders until the extent of the erosion up and down the canal and the depth have been determined. As a rule, the erosion is quite rapid until a certain shape is washed out, when it stops so long as conditions remain the same. The sides and bottom of the hole are then trimmed neatly, the former vertical in some cases, but as a rule on a slope of about $\frac{1}{2}$ to 1. Vertical posts or light piles then are driven 2 to 5 feet apart and about 6 inches back from the proposed water edge of the channel. Sometimes a few posts are driven near the bank side of the hole. The brush then is cut into uniform lengths and bound with wire into bundles about 6 inches in diameter. These are packed into the trimmed holes in layers, with their butt ends forming an even wall in the channel. Each layer of brush is brought to a smooth surface by puddling in wet earth, and is securely fastened by wires to the posts or piles previously driven, the butt ends extending about 6 inches into the channel beyond the line of posts. One layer after another is thus placed until the level of the protection is well above that of high water in the canal. In a heavily silted water this mass of brush rapidly gathers a coating of waxy mud within the interstices at the water ends of the bundles and in this condition lasts for years, some in this locality being five or six years old and still in good condition.

GATE STRUCTURES IN OPEN CHANNELS.

By far the most important, and in many cases the only structure on a ditch, is the gate placed near the point where water is diverted from the stream. In nearly all of the Western States such a gate is required by law.

DIVERSION OR RIVER GATES.

As much depends on the diversion gate and it is close to the river, whose performance is always more or less uncertain, it is recommended that a substantial and, if possible, permanent structure be built as soon as possible. Even where the general policy of the constructors is to hold the initial expenditures down to the lowest limit, it has come to be recognized that a substantial river gate inspires a feeling of confidence in the system. As long as the control remains at the river the canal below the diversion gate is not subject to ruin from floods. Local storms may injure portions of the banks, but should the river gate fail there is not much limit to the damage that can result through the lack of this control. The trouble from the Colorado River in the Imperial Valley during the years prior to 1907 was caused by this lack of control at the river.

LOCATION OF THE GATE.

Most diversion gates are located in one of the four following topographic situations:

(1) At the point where the center line of the excavated canal intersects the river bank; (2) out in the main river channel, with a built-up canal bed between the gate and upper end of the true excavated canal; (3) some distance down the canal from the point where the latter leaves the stream, with open channel between the stream water and the gate; (4) at the upper end of the canal where it intersects the bank of a secondary channel of the stream.

Variations in local conditions surrounding the sites of such gates preclude the adoption of any plans as standard, but some of the suggestions in the plans shown will be of benefit in the designing of gates under conditions which approximate those of the gate shown.

Headgate at the bank of a stream.—If the conditions of topography, anchorage, and stream flow permit, it is customary to install the diversion gate at the true excavated head of the canal. As a rule, this should be at a point where the main current of the river, especially at low-water stages, will sweep past the gate openings and carry much of the silt not in suspension on down the stream. This is partially effected by means of sand sluices adjoining the canal openings, but the results with gates built on this principle show that the designer should not expect to rid the canal of all sand at this point. There are too many whirls and eddies to insure all the sand being on the bottom of the stream, and for this reason some of it will enter the canal.

Gates placed at the original line of the river bank are not, as a rule, subject to the full force of the current during high water. Nevertheless, the general factor of safety should be much higher than for other structures farther down in the canals of the system. The great-

est factor in favor of the safety of such a structure lies in the design and construction of the upper wings and cut-off walls. If water tops, goes around, or under these there is little chance of saving the gate unless it is paved on top, so that unusual floods may pass over it harmlessly.

Headgate out in the stream channel.—Where the bed of a stream is very wide and the low-water discharge very small as compared with the floods which have determined the location of the main stream banks, it may be necessary to place the river gate out in the stream bed. It is then protected from above and below by more or less extensive cribbing or rock riprap. A canal bed, well protected on the river side by riprap, is then built up from the gate to the point where the canal line intersects the main bank of the stream.

This kind of construction also is resorted to in some cases where the river bank is more or less precipitous; it is not practicable to install a high diversion weir, and the desired canal grade intersects the river above the line of flow in time of low water. In this combination of conditions, which is quite common throughout the West, it is the usual practice to continue the grade of the ditch or canal on up the river bed, usually just under the bank of the stream, until the grade of the ditch approximates that of the stream, at which point the gate may be installed.

Headgate below upper end of the canal.—The condition spoken of in the last paragraph usually is met by constructing the ditch up the river bed as just described, but installing the gate at the point where the artificially-built bed of the ditch intersects the main bank of the stream, at which point a waste gate forms an "L" with the river gate and the surplus water is turned back into the stream.

The conditions of anchorage and foundation may not be favorable at the point where the line of the canal intersects the main stream bank and then the headgate is installed at some distance down the canal with open channel between it and the river water.

In connection with such a river gate it is most advisable to install waste gates of such capacity that the water in the channel leading to them will have sufficient velocity to keep the silt moving and not choke up the intake channel.

Headgate on bank of secondary channel.—Some of the most satisfactory structures in the West are built at the banks of secondary channels to main streams. In most of such cases the water enters from the head of the channel and is regulated roughly by logs and brush or bowlders at the point where the secondary channel leaves the main stream. In other cases the water is made to back up from the lower end of the secondary channel and in this way much of the silt and sand is confined to the main channel of the stream. The structure shown in Plate V, figure 2, is from a secondary channel

and shows a great saving in material, for the reason that the amount of water entering the channel leading to the gate can be so easily controlled that there is little danger of failure from freshets, and no excessive amount of money was necessary to build expensive wings and a high bulkhead.

In the following pages the diversion works of several systems, illustrating both the simple and more elaborate types of structures, are described.

DIVERSION WORKS OF THE SOUTH SAN JOAQUIN AND OAKDALE IRRIGATION DISTRICTS.

The combined structures shown in Plate IV furnish a general idea of arrangement for an efficient method of handling of water at the head of a canal. The joint headworks of the South San Joaquin and Oakdale irrigation districts are located in the canyon of the Stanislaus River about 18 miles above Oakdale, Cal.

The river has a maximum flood flow, as shown by two floods within six years, of 62,000 second-feet. The low-water flow is about 100 second-feet. Of the 1,500 second-feet which the structure is designed to take from the river but 1,370 feet will be delivered into the head of the canal below the lower gates, the surplus being wasted over the spillway or out through the sand and waste gate, back into the canyon below the diversion dam.

The complete heading consists of the diversion dam of two arch spans with an intervening buttress, 466 feet in crest length, and a maximum height of 78 feet, and the joint headworks on the north end of the dam and of the separate Oakdale headworks on the south end. The following description is confined to the joint headworks:

The joint headworks are built of concrete, part plain and part reinforced, installed upon and against solid rock foundations.

There are four principal elements in the headworks: First, the head wall, with five openings designed to be closed with stop logs in case of accident to the gates below; water covering the diversion dam more than 3 feet in depth tops this head wall. Second, a gravity dam placed on a tangent to the curve of the diversion dam, diverging about 16° from a right angle with the center line of the canal. There are three gate openings at right angles to the line of the canal, each 6 by 9 feet, regulated by massive cast-iron gates raised by screw stems through geared hoists located on top of the gravity dam. The top of the gravity dam is 25 feet above the crest of the diversion dam and careful estimates show that maximum flood crests will top the diversion dam about 23 feet. Third, an automatic spillway about 30 feet long just below the gravity dam at an elevation of 1½ feet below the crest of the diversion dam, and a sand and waste gate just downstream from the spillway. Fourth, three gates, each 6 feet

wide by 9½ feet high, set in suitable piers at the head of the joint canal, which shapes up after a transition section about 20 feet long into a concrete-lined channel 10.33 feet in total depth, 13.5 feet wide on the bottom, with side slopes of ½ horizontal to 1 vertical. The designed ultimate capacity of the canal will not be reached until some time in the future when the lower bank is raised and lined about 2 feet higher.

It is expected that the larger portion of silt will be prevented from entering the canal by the sluice-way trough in front of the river openings. The water will be further cleared of sand by the covered ducts below the gravity dam. The floor across the channel in a line 16½ feet above the lower gate piers slants down 2½ feet in 4 feet, while curved ribs carrying reinforced-concrete slab covers form ducts for carrying the sand out through the waste gate into the canyon.

The underlying ideas in these headworks are as follows: The velocity of the water through the structure is raised from 5 to 9 feet per second, with as little commotion as possible, by lowering the floor and curving the outside wall and lower ends of the piers so as to interfere no more than is necessary with parallel filaments of water. The wall is curved on the formula of a cubic parabola. The canal is protected from the entry of flood water by the high gravity section at the dam. The automatic spillway, waste gate, and sand sluice permit the removal of excess water and such sand as passes the upper sluice way. The lower gates accurately determine the quantity of water finally entering the canal.

In all portions of the headworks, depths, widths, and shapes were adjusted as carefully as practicable to prevent losses of head. Assuming the water level in the river to be the crest of the dam at elevation 350 feet, 1,500 second-feet of water enters at a velocity of 5 feet per second, the bottom of the head-wall openings being at elevation 341. Five feet above the lower gates this elevation has lowered 1.42 feet at the river side and one-half foot less on the bank side. The floor now falls rapidly to a uniform elevation of 338.59 feet. The velocity has increased to 9 feet per second. The floor from the upper gates falls 0.71 foot in a distance of 35 feet.

The upper sand sluiceway designed to catch sand, bowlders, etc., is at present regulated by stop logs, but it is the plan eventually to install an ordinary vertical sluice gate.

The contract price for concrete work in this heading runs from $14 to $15 per cubic yard on the basis of payment in bonds worth 80 cents, or less than $12 per cubic yard on a cash basis. The total cost will be about $40,000 in bonds. The structure was completed in November, 1912. The floors are made of a 1:3:6 mixture of cement, sand, and gravel, while most of the balance of the structure is made a 1:2½:5 mixture.

JACKSON DITCH HEADING, COLORADO.

The concrete and steel structure shown in Plate III, figure 2, was constructed in 1909, 8 miles above Fort Collins, Colo., on the Cache la Poudre River. A low diversion dam raises the river water high enough to supply the demands of the Jackson Ditch, which carries about 75 second-feet of water. The gate shutter is of sheet steel operated by double rack stems, connected by a bar which turns both pinions at once. In front of the slots for this gate is a set of auxiliary slots for the insertion of flashboards in case it is necessary to remove the steel gates for repairs during the operating season. This feature can be adopted to advantage in many gates. The sand sluice adjoins the ditch gate. The operators state that it works well but is supplemented by another sand gate a few rods below the diversion gate. In other parts of the West an installation similar to this has been more cheaply constructed by making the sand sluice merely a depression in the diversion weir, controlled with flashboards, which may be pulled during high water and replaced when the full height of the weir is needed, which occurs at a time when less sand is running in the stream. The total cost of the weir and gate structure was about $600. The concrete was mixed by hand in a ratio of one part cement to six parts of sand and gravel mixed.

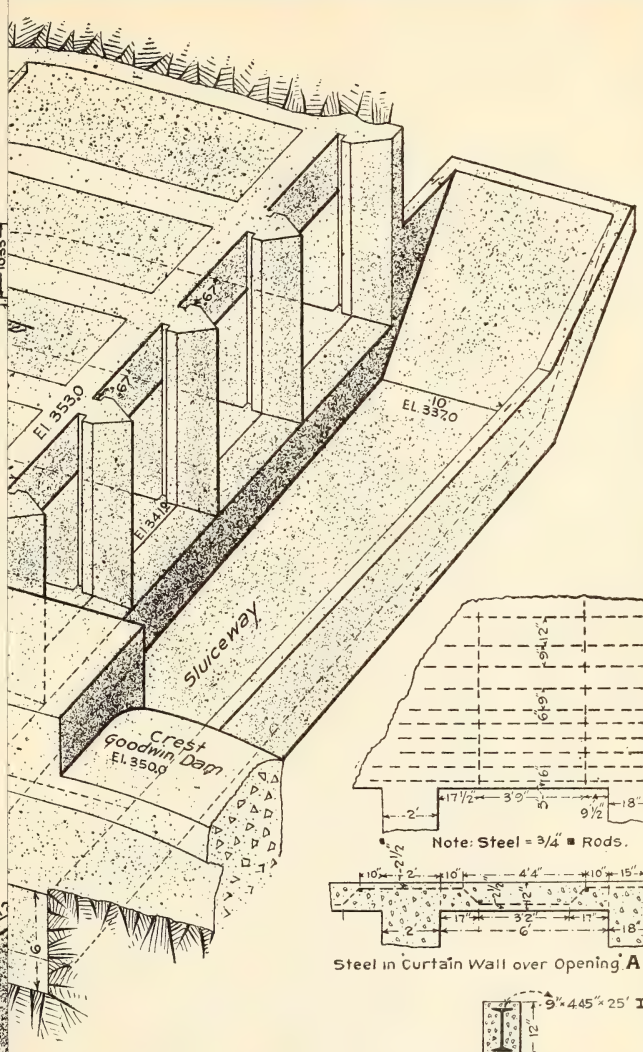
NAPESTA DITCH & RESERVOIR CO. HEADING, COLORADO.

The heading of the Doyle Arroyo feeder of the Napesta Ditch & Reservoir Co., located on Doyle Arroyo, in Pueblo County, Colo., is out on the plains 24 miles below Pueblo (fig. 1).

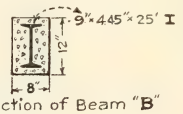
These arroyos in the vicinity of Pueblo are subject to sudden and very violent rushes of water, being dry for months at a time and then carrying a river of water for a short period. The only possible use of such water from an irrigation standpoint is to divert a large head for a short time and store the water in a reservoir. The object of this heading was to divert 850 second-feet of water from a vertical-sided wash, or arroyo as it is known locally. The sides and bottom of this wash are in shale where there is little danger of seepage under the structure, but it was necessary to protect the bottom of the wash above and the canal below the gate by a concrete apron, as the water was to be delivered under a head of several feet, through undershot gates, where the resulting velocity and scour would be very heavy.

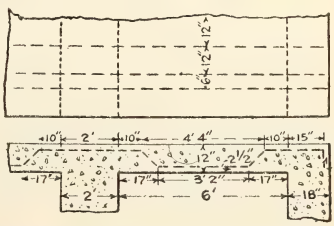
There are no sand sluices in connection with this heading, as there is little or no sand in the water, but the water is very heavy with adobe silt in suspension, which is carried on into the reservoir.

As shown in figure 1, water is checked up by a low-diversion dam extending across the arroyo. As the spring and flood flow of this wash is estimated at 3,000 second-feet and it is only 50 feet wide,



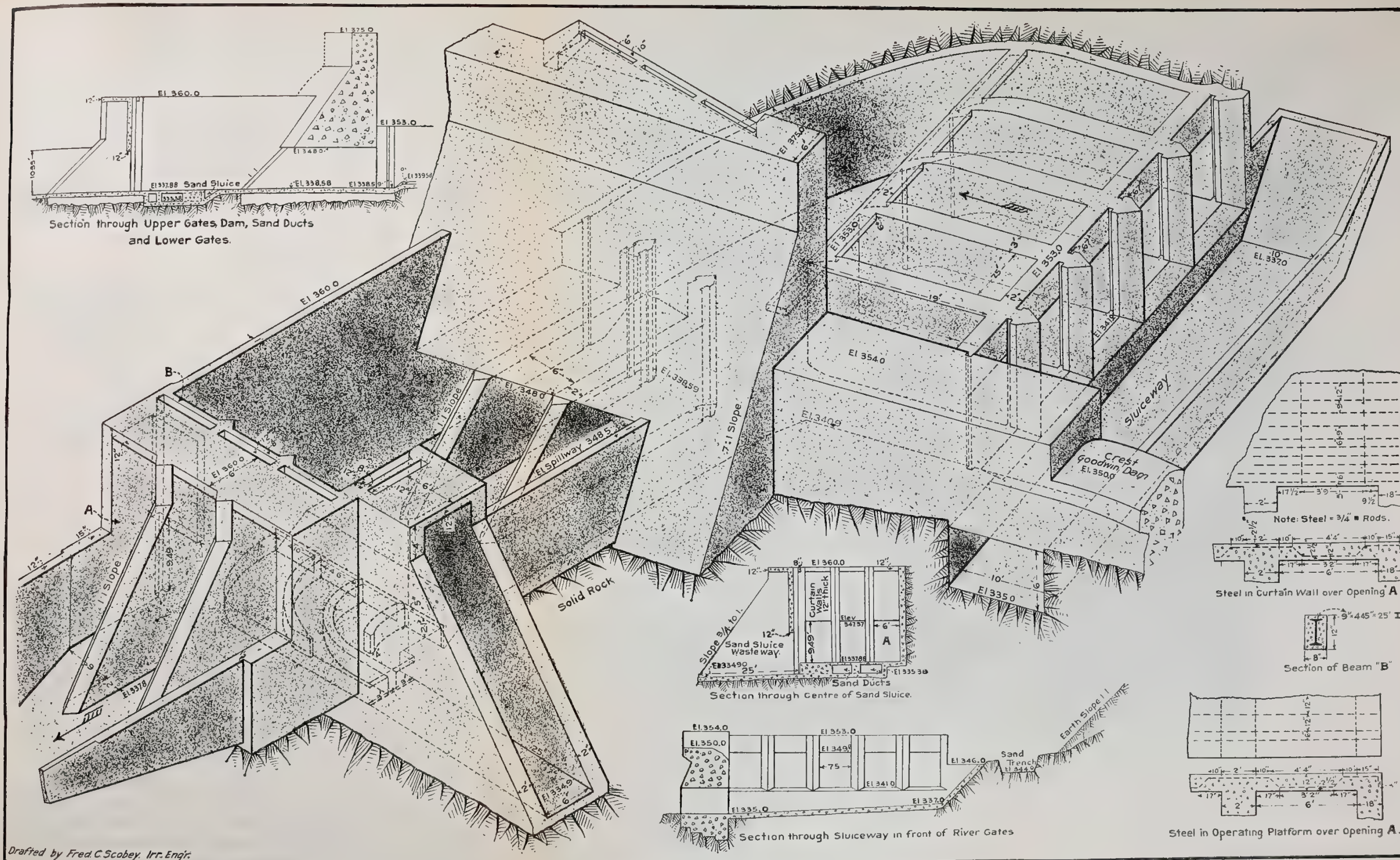
Steel in Curtain Wall over Opening **A**





Steel in Operating Platform over Opening **A**.

Section through Upper Gates, Dam, Sand Ducts and Lower Gates.



JOINT HEADING OF SOUTH SAN JOAQUIN AND OAKDALE IRRIGATION DISTRICTS ON STANISLAUS RIVER, CAL.

it was necessary to build high curtain walls above the openings in order to bulkhead out the surplus waters. The canal below the structure is 20 feet wide on the bottom, carries water 6 feet deep, and has side slopes 1 to 1. The structure as shown contains 197 cubic yards of concrete, hand-mixed in a ratio of one part cement to seven parts river gravel taken bank run. The unit cost of the concrete was about $9.50 per cubic yard. The cement cost $1.50 per barrel f. o. b. Pueblo, while the cost of the gravel was practically nothing but the digging and the hauling. Earth and shale excavation cost 40 cents per cubic yard for 110 yards.

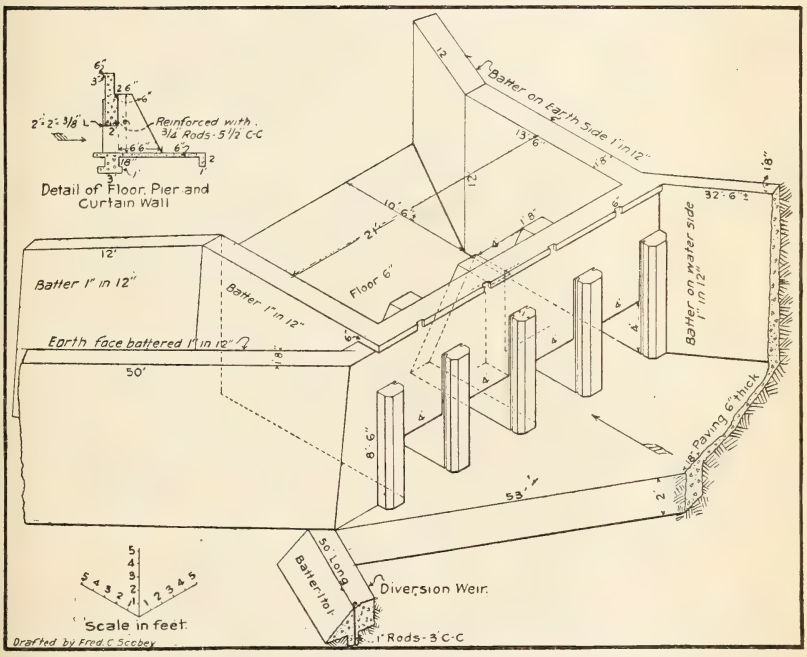

Detail of Floor, Pier and Curtain Wall
Reinforced with 3/4 Rods-5 1/2 C-C
Batter on Earth Side 1 in 12
Batter 1" in 12"
Batter 1" in 12"
Floor 6"
Earth face battered 1" in 12"
Batter on water side 1" in 12"
Paving 6" thick
50' Long Batter Pier
Diversion Weir
1" Rods-3 C-C
Scale in feet
Drafted by Fred C Scobey

FIG. 1.—Headgate, Doyle Arroyo feeder, Napesta Ditch & Reservoir Co., Colorado.

The total cost of the structure, including the steel gates, which were made in Pueblo, was about $2,500. The lifting device is the double stem, bolted together with spool spreaders, a type which is much used in southeastern Colorado.

HEADWORKS, NORTH LARAMIE LAND CO. CANAL, WYOMING.

A good example of modern construction for a headgate serving a small canal is that of the North Laramie Land Co. (Pl. V, fig. 1.) A simple and efficient form of temporary diversion dam raises the water sufficiently to secure the desired discharge into the canal. This canal is 14 feet wide at the water line, 8 feet wide on the bottom, and

will carry water 3 feet deep on a grade of 4.2 feet per mile. The gate structure has two openings regulated by steel gates, with a rack-and-pinion lift. The crest of the wings and the curtain wall above the openings are such that the maximum flood known to the stream can pass over the dam without topping the structure. The ditch below the gate is separated from the creek by a stepped concrete wall. When the writer saw this structure in May, 1912, there was about 1 foot of water passing over the weir, developing sufficient pressure on the openings to induce a velocity of 7 or 8 feet (estimated) per second in the upper reaches of the canal. As only a small amount of water was needed in the canal the gates were opened but a few inches. The high velocity caused scouring of the canal sides for about 100 feet below the gate. This condition suggested that the water might be delivered to the canal much more gently by casting some flashboard grooves in the sides of the gate structure downstream from the openings so that boards might be inserted in these grooves and the elevation of the water below the gate kept at such a height that the shutters could be opened wide and the velocity of the entering water correspondingly reduced. The water would fall over the flashboards in a vertical drop and the velocity of the water below the structure cause no damage. If the full capacity of the canal should be desired, the flashboards would be pulled and the elevation of the water in the canal would prevent high velocity at the upper end.

At the time the photograph shown in Plate V, figure 1, was taken all of the water not entering the canal was passed through the sluiceway in the diversion dam. This not only serves to carry most of the sand down the stream, but also makes it possible to draw off the water below the crest of the dam in order to make repairs.

HEAD GATE, UINTA COUNTY IRRIGATION CO., WYOMING.

A good example of modern construction of a river gate for a canal diverting water from a secondary channel of the stream is furnished at the head of the Cottonwood Canal in Uinta County, Wyo. (Pl. V, fig. 2.)

Ball Island separates the stream into two branches and the gate is installed on one of these. The amount of water flowing in the branch supplying this gate can be regulated roughly by logs and brush in the channel at the head of the island. This regulation prevents the heavy flood flow of the stream from coming with full force against the gate structure and the saving in construction, due to this safe position, is evident from the view shown. It will be noted that the wing walls do not rise far above the natural surface of the bottom land.

This gate supplies a canal 20 feet wide on the bottom with water 3 feet deep. The carrying capacity is 140 second-feet. The gate is

set in a cut in cemented gravel 5 feet deep. The canal below the structure is in this same class of material, so that it forms a natural paving which does not erode easily.

The Uinta County Irrigation Co. constructed this system under the conditions of the Carey Act. This particular structure was built by force account in 1911. The steel gates proper and fittings, which were made in Denver, Colo., weigh 5,700 pounds. Cement cost 80 cents per hundred pounds f. o. b. Opal, a station on the Oregon Short Line 60 miles by wagon from the work. Sand, water, and gravel

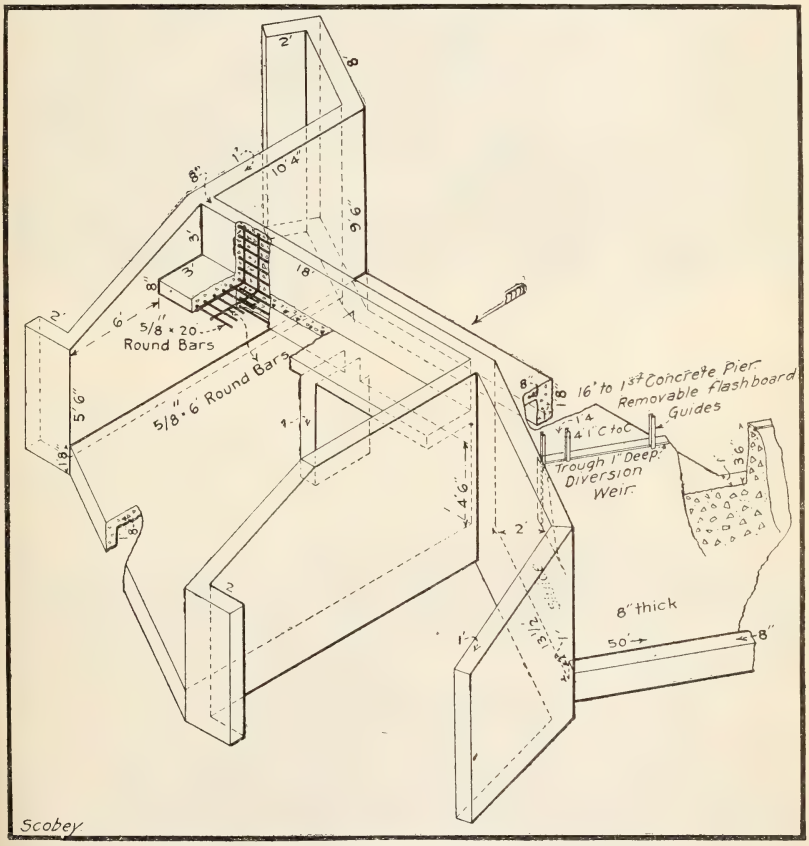


FIG. 2.—Concrete portion of headgate, Highland Ditch Co., Colorado.

were close at hand and cost nothing but the labor of one handling. The cost of the structure was $820.

HEADING, THE HIGHLAND DITCH CO., COLORADO.

The heading for the inlet ditch of the Foothills Reservoir, located in Boulder County, Colo., about 10 miles from Longmont, is a good example of a diversion from a stream which is plentifully paved with heavy cobblestones. (Fig. 2.) This paving forms a natural

riprap, effectually preventing scouring of the bottom above and below the structure, which eventually would cause the failure of the gate through undermining but for these cobbles. On this particular structure, as shown in figure 2, the cut-off walls extend but 12 inches below the bottom of the floor. The ditch headed by this gate is 14 feet wide on the bottom and has a maximum carrying capacity of 400 second-feet, to be diverted from St. Vrain Creek, which has a normal flood flow of about 1,100 second-feet.

In order to raise the crest of the diversion dam in times of very low water, a set of flashboard guides is loosely placed in tin-lined holes in the concrete dam proper, the tin acting as the form for the holes when cast. The original plans called for a concrete footwalk over the weir, from which it was possible to pull the flashboards and also the guides in times of very high water, so that the obstruction offered by the weir could be reduced to a minimum. These plans were afterwards changed and a plank walk loosely bolted to the piers was substituted. A flood of sufficient size to cause damage to the structure would break these boards, and there would be no obstruction to the passage of trees and heavy débris, with the exception of the piers, which are placed so that a net opening width of 16 feet remains between them.

This structure was built in 1911. Including the bridge in connection, it contains 90 yards of concrete, reinforced with five-eighths inch twisted bars. The concrete was machine mixed in a ratio of 1:3:5 cement, sand, and river gravel. The construction was carried on by force account, and the total cost of the structure, excepting the iron work of the gates proper, was $450. Cement cost $1.75 per barrel at Hygiene, on the Burlington Railroad, 4 miles distant. The foreman was paid $100 per month, and common labor cost $2.25 per day. The total engineering charge against the structure was $40. The iron gates cost $75, in addition to the $450.

HEADWORKS, SOUTH BOULDER AND COAL CREEK DITCH, COLORADO.

A short distance above the town of Eldorado Springs, on South Boulder Creek, Colorado, the South Boulder and Coal Creek Ditch diverts 53.55 second-feet of water. As shown in Plate VI, figure 1, the creek at this point has a very rapid fall in a canyon. The bottom is strewn with bowlders from the size of a cobblestone to that of a small house.

The diversion dam is a makeshift of boards spiked to a heavy cross timber which is braced against the bowlders of the creek, the whole structure being weighted with a sloping pile of loose cobblestones.

The gate structure has 8-inch concrete side walls 10 feet long which bond with the bowlders of the canyon, in effect merely squaring up the face of the bowlders. Two vents are formed by a central

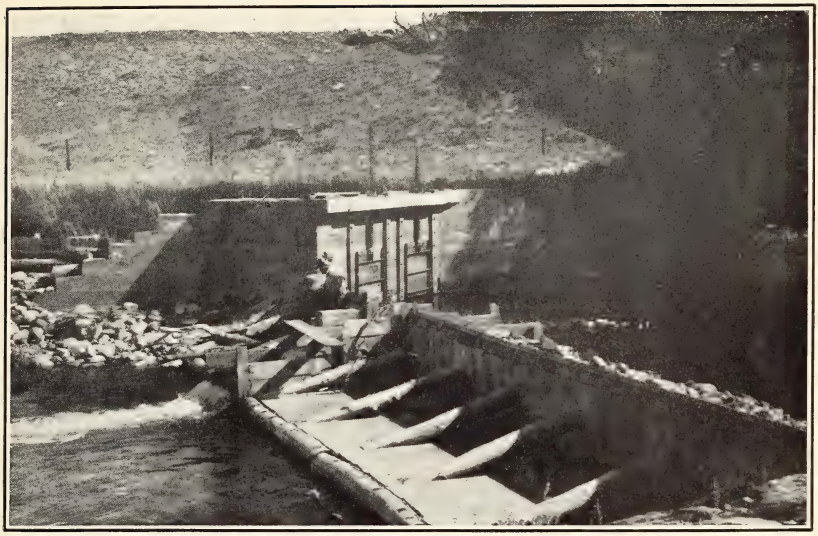


FIG. 1.—DIVERSION DAM AND HEADGATE, NORTH LARAMIE LAND CO. CANAL, WYOMING.

FIG. 2.—HEADGATE, COTTONWOOD CANAL, UINTA COUNTY, WYO.

FIG. 1.—HEADWORKS, SOUTH BOULDER AND COAL CREEK DITCH, COLORADO.

FIG. 2.—BIFURCATION WORKS, HOLBROOK IRRIGATION DISTRICT, COLORADO.

concrete division wall 8 inches thick. The gate shutters are each 2 feet 4 inches wide, sliding in 2 by 3 inch grooves. The individual boards are of 2-inch stuff firmly bolted to a wide gate stem of the same thickness, which is bound around the edge securely with an iron strap. Small bolts pass completely through the gate stem edgewise and hold the strap to the stem. The outside gate slots are cast in the concrete, while the inside slots are built up of timber secured to the division wall by anchor bolts. The 4 by 4 inch cap for the locking device is secured to the side and division walls by anchor bolts. Staggered holes for the locking pin are bored in the stem shutter and cap. The concrete is a mixture of one part cement to six parts sand and gravel found near the site. The total cost was $225. The items were not obtainable.

As the canyon is subject to very rough flood waters which may overtop the gate at any time it was desirable to keep the superstructure as low as possible, so that the gate standards were not set high enough for the locking holes to be bored in the stem alone, which would leave the shutter proper a solid panel. In order to secure a locking position for the shutters when wide open, it was necessary to bore the holes nearly to the bottom of the gate, and these cause a bad leakage when the gate is closed. A better construction to secure the low superstructure probably would have been a wooden radial gate extending from one side wall to the other, omitting the division wall; or, if desirable to use a slide gate, the use of the angle-iron stem shown in Plate I, *i*. The double concrete flume below the shutters is covered with a timber footbridge for a trail leading up the canyon.

BIFURCATION WORKS.

These structures are used to divide the water of one canal or lateral between two or more canals or laterals. This division may be on a proportionate basis or otherwise. A structure may be used to divide water all of which is handled by one company, or it may be used to segregate for one company water which has been carried in the canal of another company up to the point of bifurcation. If the conditions of water rights and the arrangements between the companies call for a proportionate division of whatever flow is in the supplying canal, then the openings should be so arranged that any change in the head of water will affect the discharge of both proportionately.

Where the division of water is to be nearly equal and the topography permits, it is usual practice to design a twin structure placed symmetrically with regard to the supply canal. In this way each gate is affected equally by the various factors of approach velocity, contraction, etc. If one division is to receive only a small portion of the water, the usual practice is to hold the alignment of the sup-

ply canal for the larger of the two canals and change the direction of the smaller channel. This involves about the same construction as a check gate and a lateral delivery, the check serving as the head gate of the larger of the two divisions and the lateral gate as the head gate of the smaller division.

The relations between the two companies receiving water from a structure of this class may be such that the designer is called on to attach locking devices to either or both of the division gates. This condition may involve a more expensive form of gate shutter than would be required if the water is to be divided between two canals of the same organization.

BIFURCATION GATES, HOLBROOK IRRIGATION DISTRICT, COLORADO.

About 9 miles below the head of the Lake Canal of the Holbrook irrigation district, in Otero County, Colo., the inlet canal to supply

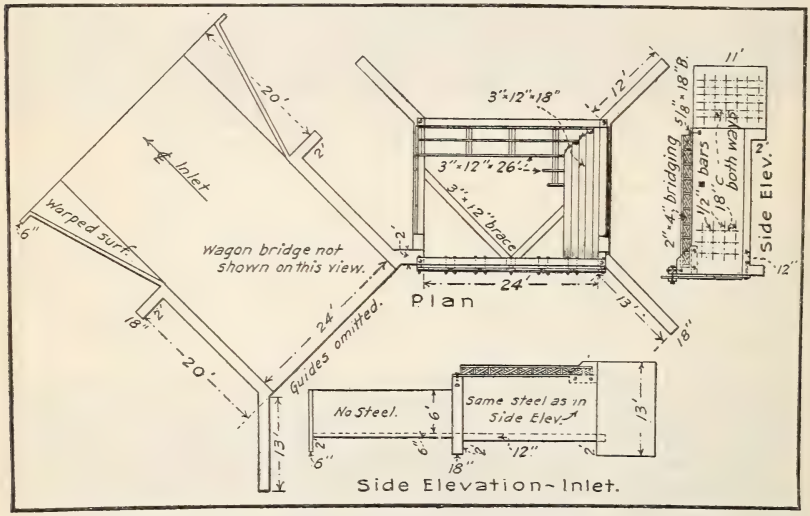


FIG. 3.—Bifurcation works on Lake Canal, Holbrook irrigation district, Colorado.

Dye Reservoir leaves the main canal. The regulation of water between these two is effected by means of the twin structure shown in Plate VI, figure 2. This structure illustrates very well the general practice in Colorado of combining wood and concrete. It is noted that the wings, floor, and side walls are of concrete, while the gate shutters—shown in detail in Plate I, *f*—the front guides, and the whole bridge structure are of wood (fig. 3). As these parts are all bolted to the concrete they may be replaced as they rot out, whereas the portions most difficult of access are made permanent.

The canal leading to the structure is 30 feet wide on the bottom, 7 feet deep at the water line, and has a capacity of 1,000 second-feet.

The gates in the main canal are placed at right angles thereto and the gate leading into the reservoir inlet canal is set at an angle of 45° with the main canal and at right angles to the inlet canal.

The use of a wooden slide gate for openings of this width, 12 feet, is rather unusual, and the writer would suggest the use of wood or steel radial gates in adapting these same general plans if the regulation to a great degree of accuracy is not required, and there is to be very much changing of the gates. Many bifurcations of this sort—supplying a reservoir—do not require to be changed more than once or twice in the course of the year, all the water being turned to the reservoir during the winter and early spring and then the inlet to the reservoir closed for the balance of the season and the main canal gates left open. In such cases economy in gate shutters at the expense of time and labor for one or two operations a season may be recommended.

This structure was constructed by contract at a time when common labor cost $2 and teams $4 per day. Water was close at hand; sand and gravel were hauled 1½ miles and cement and lumber 3 miles. The district furnished at the site all steel, hardware, and lumber except forms that went into the structure. Cement was furnished, mixed, and placed by the contractor. The successful bid was as follows:

For concrete in place, including the setting of all anchor bolts and placing steel reinforcements, $8.65 per cubic yard.

For labor, framing, and completing gates (shutters), bridges, etc., $12.75 per thousand.

For all excavation required for concrete, not included in inlet ditch, $0.34 per cubic yard. (The above quoted from contract.)

The total cost was $2,685.48.

DIVISION GATES.

Bifurcation works on a small scale are usually called division gates or division boxes. As a rule, they divide water between two small laterals, between one consumer and all others below him on a lateral, or very small ones are used by a single consumer to distribute the water in his head ditch to various parts of his land, the various shutters being used alternately as check and delivery gates, depending on where the water is to be sent.

DIVISION BOX, SHELL CANAL, WYOMING.

Plate VII, figure 1, shows the type of construction used to divide the water of a lateral 8 or 10 feet wide between two smaller laterals. The water in the foreground is turned to one or the other or both of the small laterals leading to the right and left of the picture. Simple flashboards are inserted in the slots as shown. Where the

laterals are very small, the velocity low, and the possible pressure head not more than 2 feet an "L" structure of a simple wall of concrete might be used, with one leg of the "L" at right angles to each of the smaller laterals with slots in the ends of the walls where the water openings occur.

COMBINATION DELIVERY GATE, DIVISION BOX, AND MEASURING WEIR, CONSOLIDATED LOWER BOULDER RESERVOIR & DITCH CO., COLORADO.

There has been designed and installed for the Consolidated Lower Boulder Reservoir & Ditch Co., of Longmont, a small concrete and iron structure which takes the place of a delivery gate, with an adjustable shutter, lockable at the various positions of the gate shutter. This shutter is shaped and placed under conditions approximately correct for the Cipolletti weir, which gives a very close measuring device through the orifice of the gate.

The plans shown in figure 4 are for a box to be placed at the lower end of a small lateral, the water to enter the structure as shown by the arrow. The three weir openings allow water to be delivered to any one or more of these farmer's ditches, one leading from the box in the same direction as the flow of water toward the box in the lateral and the other two leading off to either side.

A modification of this structure allows a delivery to one side only, the continuation of the lateral leading off from the structure either at the other side or at the end opposite that through which the water entered.

The construction where a delivery is to be made to either side and the lateral continued from the box is similar to the first case taken above. Each of the openings leading from the box is provided with an adjustable cast and wrought iron Cipolletti weir, as shown in the details of the drawings. There are two equal and symmetrical cast-iron plates each three-eighths inch in thickness, sliding between wrought-iron guides. The inside edges of these plates have a slope of $\frac{1}{4}$ to 1, and give the correct conditions for the Cipolletti weir, aside from any velocity of approach, which must be guarded against. When the plates are wide open the weir is 3 feet long on the cast-iron crest. The latter is stationary, and set 15 inches above the bottom of the box. On the assumption that the depth of water over a weir should neither exceed one-half the distance from the weir crest to the bottom of the supply channel nor one-half the distance from the ends of the weir crest to the sides of the supply channel the maximum allowable depth over the weir is $7\frac{1}{2}$ inches.

A delivery to the maximum of 5 second-feet may be made to any one of the branches and still use the measuring device. As the slides are closed the weir condition changes from that of a Cipolletti weir

to a " V " notch, and the opening finally is closed completely when the slides lap each other to the extent of 3 inches. As the weir is shortened the discharge increases over the formula discharge as soon as the depth exceeds about one-fourth the length.

The stationary weir plate A is bolted into the concrete wall of the box and extends 3 inches inside the edge of the concrete at both

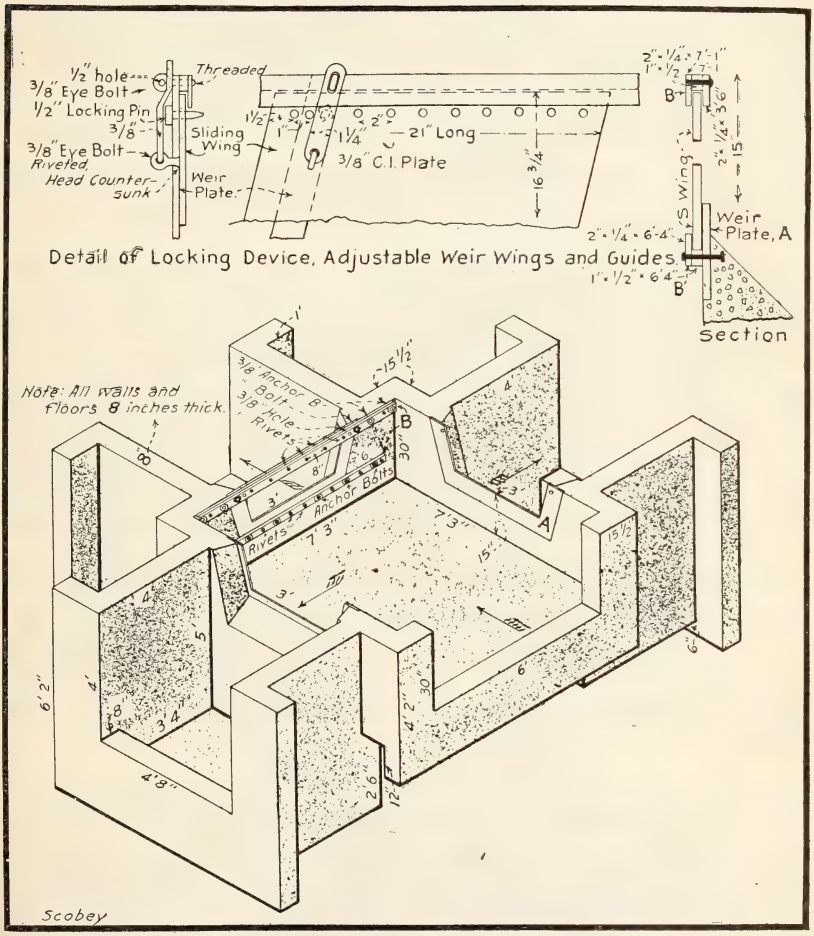


FIG. 4.—Three-way division box of Consolidated Lower Boulder Reservoir & Ditch Co., Colorado.

sides and at the bottom. Bolted to the wall and extending across the box are two guides—B–B—formed of pieces of wrought iron, the upper one 7 feet 1 inch long and the lower 6 feet 4 inches long. Each is 2 inches wide and one-quarter inch thick. The guideways are formed by riveting the above pieces to a filler piece of wrought iron of the same length as B–B, but 1 inch wide and one-half inch

thick. The rivets are countersunk on the side coming against the concrete.

The gate shutters or slides are 16¾ inches high and 21 inches long, the back end being cut parallel to the front end. Near the top of these shutter pieces is bored a series of holes five-eighths inch in diameter. These holes come just under the lower edge of the upper guide and pass corresponding holes of the same size in the stationary plate. Either slide is locked in any desired position by passing a pin through the proper hole in the slide and fastening it there, as shown in the drawing. This forms a positive locking device, and the slide can be moved only under action of the key. If the ditch regulations on a system desiring to adopt such a device as this are such that the consumer is allowed to open his gate to a certain point, determined by the lock, but can close it at will, a modification of the structure may be effected as follows:

Cast two flashboard grooves in the side walls of the outlets below each weir so that boards inserted therein will close up the opening leading from the weir. By adjusting these the consumer can close out any part of the water and yet he can not take water to exceed the capacity of the locked weir. Of course it is to be understood that any gate which allows the consumer to turn water back into the ditch causes that much more water to come against the succeeding gates, with an increase in the discharge through these other gates. If flashboards are undesirable then a simple wooden slide gate may be made to fit the grooves:

This construction as installed by the company, made under force account, costs about $8 per cubic yard for concrete of a 1:3:5 mixture of cement, sand, and river gravel. Cement costs $1.85 per barrel. A structure with 3-foot weirs costs about $32, while one with 4-foot weirs costs about $40. These prices include the shutters and locking devices.

WOODEN DIVISION BOX, MONTANA.

In parts of Montana the division box shown in figure 5 is used to turn all or any part of the water in one small ditch into a head ditch or field lateral leading from the supply ditch. In the gate shown 2-inch material is used for the most part, but in sections of the West where redwood is available 1-inch stuff would do almost as well for the flashboards, sides, bottom, wings, and cut-offs, using 2 by 4 inch redwood or Oregon pine for the posts, sills, and caps. If it is not desirable to use flashboards one of the simple wooden shutters shown in Plate I may be adapted to fit. The gate shown is for a one-way division from the supply. For a two-way division the structure is made symmetrical, both deliveries being made like the one delivery shown.

PROPORTIONAL DIVISION BOXES.

In parts of Utah and northern Colorado and in other places in the West a type of structure is used which is supposed to divide whatever water there is in a ditch in a proportional manner. As a rule this division box is used on rather small ditches, owned by a few men as partners or a small group of men organized as a cooperative company. The general manner of division is the same in either case. Assume the organization to be a small cooperative company in which a share of stock entitles the holder to the same proportion of what-

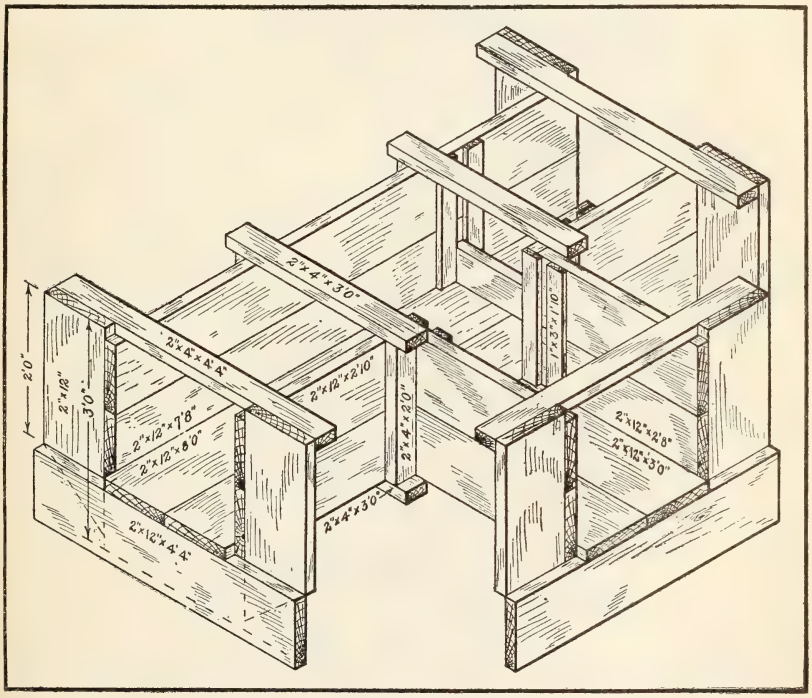


FIG. 5.—Wooden division box, Montana.

ever water is turned into the ditch as one share bears to the total number of shares in the company. Assume the total number of shares of stock to be 36 and that the first stockholder on the ditch has 11 shares and the second one 8 shares. The first division box, therefore, is to turn out eleven-thirty-sixths of whatever water is in the ditch, and the second box is to turn out eight-twenty-fifths of the remaining water. The denominator becomes 25 for the reason that after delivering water to the 11 shares the water remaining in the ditch represents 36 less 11, or 25 shares. This procedure is carried out to the end of the ditch.

Suggested design for proportional division box.—The structure shown in Plate VII, figure 2, is a very common and very faulty type of installation. The division board is set so as to divide the check board in the box in the same proportion as the water right of

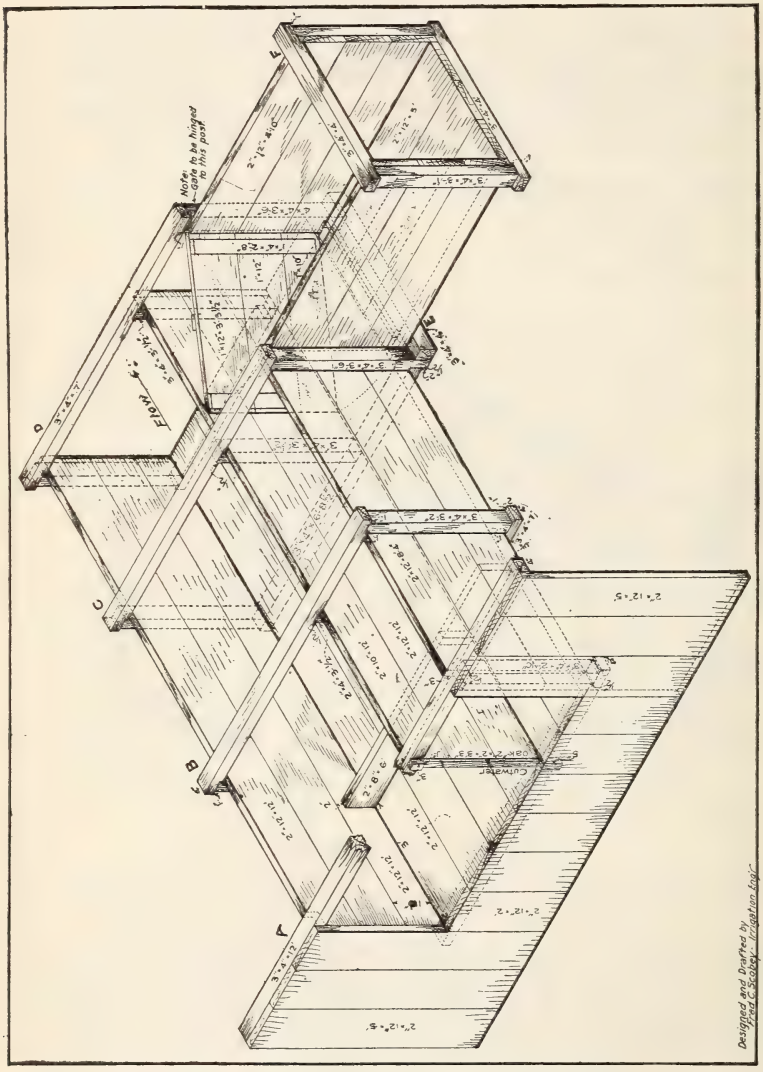


FIG. 6.—Design for proportional division box.

the consumer taking water through the small opening at the left of the box bears to the total water in the ditch. The area of the cross sections of the water in the two portions of the box may be proportional in the correct ratio, but the discharge through each part of the box equals the area multiplied by the velocity, and the latter is

so retarded along the edge of the ditch by grass, rocks, and other friction elements that in the case photographed the water flowing out of the small division at the left of the box had a velocity about one-fifth that at the middle of the box. Also in the case shown in the plate, the conditions of contraction are not such that the discharge over the check or weir board is proportional to the length. The division board should have been extended as far upstream from the check board as the side walls so that the contraction of the current would be completely suppressed by the time the water reached the board, and then the discharge would be proportional to the length, provided the velocity is uniform across the weir or check board. To secure this last condition it is better to pool the water above the box by widening and deepening the ditch or by installing baffle boards in some form. The nearer still the water is above the box the more nearly accurate is the division.

As usually installed there is a very appreciable velocity toward the box, and the diverted water is less than the figured proportion for the reason that it is diverted at the side of the ditch while the greatest velocity is near the middle. The only thing that can be said in favor of this erroneous division is that the consumers at the head get less water than they are entitled to, and in this way involuntarily contribute water to the ditch to help pay for the losses by seepage and evaporation below their gates. If the division were brought about exactly as intended, then the stockholders at the lower end of the ditch would have to stand the brunt of the losses. The best way, from a theoretical standpoint, is to determine what the losses in transmission actually are and take them into consideration in determining the position of any particular division wall. Figure 6 shows a wooden division box designed to apportion out water quite accurately provided the water has but a very low velocity toward the box.

The box as designed by the writer and shown in figure 6 will deliver water to 11 shares of stock out of a total of 36 shares. That is, the net opening leading to the delivery box bears the same ratio to the total width of opening as 11 bears to 36. Assuming the division wall to be of 2-inch lumber, then the total width of opening is 70 inches. On this basis the position of the division wall is found by the following proportion:

$$\frac{x}{70}=\frac{11}{36}$$

where x is the desired width of the opening leading to the delivery box, expressed in inches. Therefore

$$x=\frac{70\times 11}{36}\text{ or }\frac{770}{36}$$

which equals 21.39, or 21⅜ inches expressed to the nearest sixteenth of an inch. Therefore on the plans as shown the width of opening for the smaller channel would be 21⅜ inches; then comes the 2-inch division board and then the remainder of the 6-foot width of main box, or 48⅝ inches.

Assuming that the width of the ditch remains about the same and that the next consumer has 8 of the 36 shares of stock, after passing the first box the water represents 36 shares less 11 shares, or 25 shares, and the width of the opening leading to the delivery box becomes

$$\frac{x}{70}=\frac{8}{25} \text{ or } x=22.4 \text{ or } 22\tfrac{3}{8} \text{ inches.}$$

Note that all of the posts supporting the division wall are set in the larger channel for the reason that any influence due to these posts would affect the larger channel less in proportion than the smaller one. These posts go through the floor but are not set into the sill as are the outside posts. The check or weir board goes completely across both channels and the lower board of the division wall is cut to set down over the check board. For a large division box on this plan, or where the soil of the channel below the box is eroded easily, a lower cut-off wall and a wing on the side opposite to the delivery box should be added to the structure.

The siding and floor of this structure are given as 2-inch stuff. In southern California, where densely fibered redwood is obtainable, 1-inch stuff would suffice. The thickness of the boards may be altered to suit the local lumber.

The only piece of hardwood in the structure is the cutwater, which should be of oak or it will not last long. It should be screwed into the ends of the division wall boards and tightly screwed to the cap and to the sill. This construction saves the use of any side posts above the weir board, which posts would alter the proportionate division of water. Thin strips of sheet iron may be fastened to each side of the division wall with stove bolts to strengthen it. The upstream side of the cutwater is beveled to a knife edge, as shown, from the floor to the cap. It is to be noted that the width of the division board is deducted from the total width of the main box; that is, 2 inches is deducted from 72 inches, leaving 70 inches to be divided proportionally.

The weir board is placed 3 feet down the channel of the box in order to suppress the contraction and make the flow over the board approximately proportional to the length between walls. This box is designed to be used where there is not sufficient fall to the land to make a clean drop in the ditch at the division box, but this board will reduce the influence of the water below the board so that the

flow is divided as nearly proportional as the expense will justify. Greater refinements of division mean greater cost to the device in length of channel, baffle boards, etc. The weir board need not be made sharp for this kind of a box, as the discharge over the square edge is quite proportional to the length of the crest. Even though partially submerged, the two discharges will hold the true proportion quite closely.

When it is desired that no water be turned to the delivery box, then the gate is closed on its hinges and the water passes through the box and back into the channel below the box, keeping both sides of the division wall clear of silt. The crack under the gate, left so that the gate may swing freely, is closed by a stop board nailed across the channel of the delivery box, as shown. The box contains about 650 feet b. m. of lumber.

LATERAL HEADGATES.

It is a difficult matter to draw the line between a lateral headgate on one system and a delivery gate on another. In this publication structures will be classed for the most part in the way they were classed by the companies using the plans in question, but the reader should understand that most of the comments on the conditions of divergence for a lateral gate are applicable also to a delivery gate, turnout, or whatever this class of structures may be called in the particular part of the country in which they are made.

Lateral headgates divide themselves naturally into two distinct classes—those having essentially a tube of some form through the bank, and those which take an open-box culvert form. The first type preserves the continuity of the surface of the levee for road or other purposes, and the second breaks the levee surface and must be bridged if the levee is to be used for a continuous road. Small laterals may be served by either type, but as a rule very large laterals receive their water through the open-box type.

Another important factor entering the decision as to which type to use, is the relationship between the top of the bank and the canal water. Where the bank crest is more than 5 or 6 feet above the water to be diverted it is better to use the tube type for comparatively small laterals, as the height of the side walls, with the added detrimental feature of the break in the canal bank, causes greater expense than would be required of a tube delivery.

The tube form is desirable, especially in cases where the canal occupies a supported position along a hillside and a drop of some form is necessary between the canal and the general level of the land which must support the lateral after it leaves the canal.

The open type of gate replaces the levee for the width of the gate, and it must be prepared, therefore, to withstand all of the conditions of variation in water level in the canal that are required of the levee. The front, wing, and side walls need not be any higher than the crest of the levee adjoining the structure. On the other hand, if they are lower, then the high-water line in the canal is lowered accordingly. It may be desired to have the lateral gate act as a spillway for surplus water to pass from the canal into the lateral and on into some natural drainage. Such a condition as this may be met by so designing the front of the lateral gate structure that water may top it and be collected in the culvert below without damaging the anchorage within the wing walls.

The same thing may be said of the tightness of the shutters in a lateral gate as of a check gate. If the shutters act as regulators only and there is always more or less water being delivered into the lateral, then there is no necessity for the gate to be water-tight, but if the lateral is of such small size or the conditions of delivery are such that water is turned out for intervals, then it is desirable that the structure be made water-tight. This is true particularly when the water carries silt in suspension.

Experience has shown that it is very desirable to design a structure leading from a canal so that the general shape of the canal bank is changed as little as possible. This is comparatively easy to do when a lateral gate is designed to be placed in the bank after the canal has been operated for some years and the bank has assumed the general form which will remain and which may be called one of the individualities of the canal at that particular point. This change in the shape of the levees or banks is very marked in most systems. When first constructed the loose earth usually takes a slope of 1½ or 2 to 1, but after some years grass and weeds appear on the levees and the bank near the water line stands nearly vertical, overhung with earth and grass in many cases, while the slope near the bottom becomes flatter than it was in the initial construction. When this final position of the canal banks can be determined, then the face of a delivery structure may be made to conform to and be flush with the steeper slope, and if the shutters are set well to the front of the gate structure there will be very little break in the canal bank and the cost and trouble of maintenance due to the deposits caused by eddies and quiet water in nooks in the canal bank will be reduced to the minimum.

The system of delivery through a lateral gate may be such that a constant quantity is desired regardless of fluctuations in the surface of the water in the canal, or it may be such that it is desired that any fluctuation in the water of the canal be shared in proportion by the lateral.

FIG. 1.—DIVISION BOX, SHELL CANAL, WYOMING.

FIG. 2.—FAULTY PROPORTIONAL DIVISION BOX.

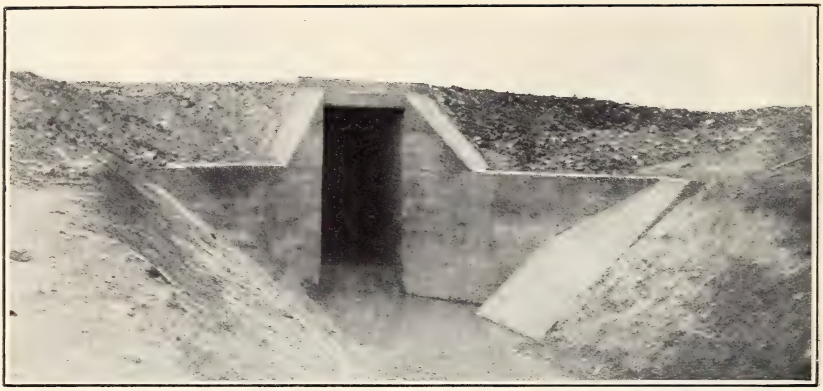


FIG. 1.—HEADGATE, LOW LINE LATERAL, ROCK CREEK CONSERVATION CO., WYOMING.

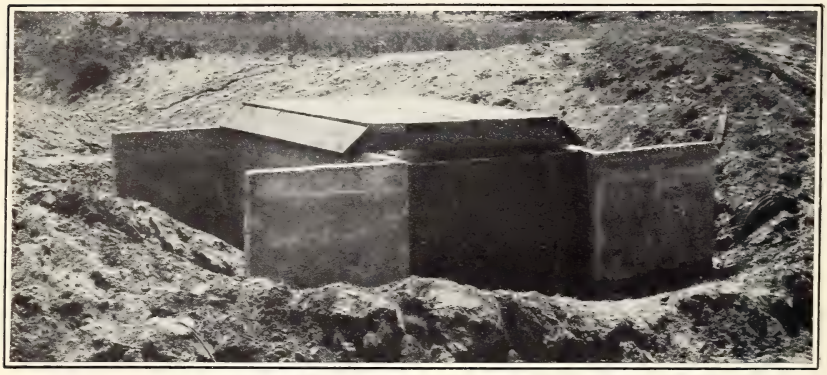


FIG. 2.—RADIAL DELIVERY GATE, TURLOCK IRRIGATION DISTRICT, CALIFORNIA.

FIG. 3.—DELIVERY GATES ON NORTH POUDRE CANAL, COLORADO.

If the first condition holds, then it is easier to maintain a constant delivery by an undershot gate, as the discharge through such a gate varies as the square root of the head on the opening, while the discharge over a crest varies as the cube of the square root of the head. Thus, the best combination of check and delivery for the purpose of delivering a constant head is to check the water up to pass over a crest, the wider the better, and to pass the delivered water under a gate. If the second condition holds, then it is desirable to deliver the water in the same way as the water passes the check; that is, if the check has an undershot discharge, then the water should be deliv-

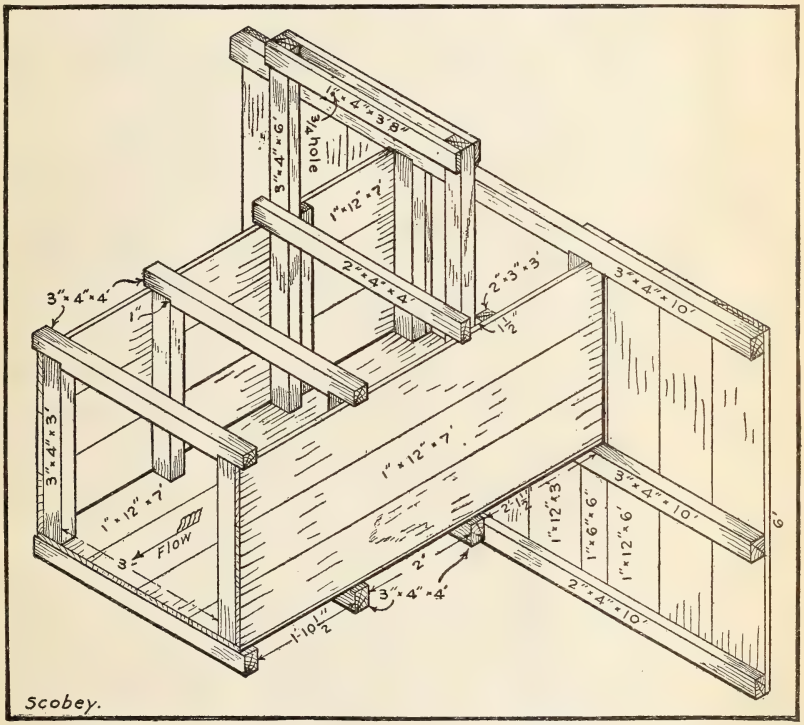


FIG. 7.—Small lateral headgate or delivery gate, Imperial Valley, California.

ered under the gate, but if the check is a crest device, the water delivered should then be passed the same way and the ratio of the crest lengths should be in the same proportion as the desired ratio of delivered water to volume allowed to pass on down the canal over the check, the crests being set in the side walls so that the contraction is practically suppressed.

SMALL LATERAL HEAD GATE OR DELIVERY GATE.

The water companies in the Imperial Valley, Cal., use a box on the general plans of the one shown in figure 7. This is a modifica-

tion of a similar gate designed by the engineers of the California Development Co. The joists, floor, wings, cut-off, and walls are of redwood, and the other members are of Oregon pine. The whole structure, including the shutter—similar to the one in Plate I, *c*—contains 222 feet b. m. of lumber. These gates cost $20 to $25 in place. Two-inch material for the floor, sides, and sheet piling, instead of 1-inch, will be necessary for most lumber obtainable in States where redwood is not handled. The cracks should be battened for clear water, but the plans shown are for silted water. If the ground is eroded easily a cut-off and wings similar to but smaller than the front ones should be added at the lower end. Some of the water companies add an 8-inch weir board under the gate shutter to develop partial contraction and then measure the delivered water as an open-air or submerged orifice, as the case may be, using a coefficient of 0.62, but nearly all the gates deliver more than the rated amount of water, due to velocity of approach and imperfect contraction.

On the gate as shown the floor extends under the side walls. A better practice is to let the side walls come outside of the floor. In such case the settling of the floor boards to a slight extent does not develop a crack through which water escapes and does damage.

HEADGATE, LOW LINE LATERAL, ROCK CREEK CONSERVATION CO.

The Low Line lateral of the Rock Creek Conservation Co. of Rock River, Wyo., receives water from the Bosler No. 3 ditch. It is 10 miles long, 8 feet wide on the bottom at the head, and carries water 4 feet deep on a grade of 2.64 feet per mile. The rated capacity of the lateral is 135 second-feet, to serve 10,000 acres of land.

The structure, built in 1911, at the head of the lateral, also serves as a wagon bridge. (Pl. VIII, fig. 1.) No check structure is placed in the main ditch, as the lateral starts out down a slope so steep that drops are necessary, and it was desirable that the lateral headgate be placed as low in the main ditch as possible. The structure is of concrete with steel gate shutter and lift.

The shutter is placed in a vertical position at the line of the water side of the bank crest. A penstock 5 feet wide, with side walls 18 inches thick sloping down on the top from the height of the bank to 4 feet above the floor, leads from the main ditch bottom to the shutter. The floor slants down 2 feet from the grade line of the ditch to the gate opening. The latter is 3 feet $7\frac{3}{4}$ inches high and 3 feet 4 inches wide under a curtain wall 1 foot thick.

The floor extends 15 feet downstream from the gate shutter and then drops 4 feet vertically into a water cushion 10 feet long. At the lower end of the latter a vertical raise of 2 feet makes the net

drop in the structure 2 feet. The side walls through the bank are 5 feet apart and 18 inches thick, carrying a bridge slab 6 inches thick for a roadway 6 feet wide. This slab is reinforced the short way with half-inch rods placed 6 inches on centers. Below the bridge the lower wings, which are 6 inches thick, slope down from the bank-crest height to 6 feet above the floor.

The vertical sides of the water cushion are 10 feet high, 18 inches thick, and flare at an angle of 30° with the axis of the ditch. Below the cushion the lateral is lined for a distance of 10 feet with 6 inches of concrete, the sides sloping up at $\frac{1}{2}$ to 1 from a bottom width of 8 feet. The earth section below the lining shows signs of erosion for a short distance, so it probably would have been better to construct the water cushion about 5 feet longer or line the lateral 8 or 10 feet more.

There is a 4-foot cut-off at the canal end of the structure and a 3-foot cut-off at the lower end. Each of these is 1 foot thick. The gate proper is of sheet steel with a rack-and-pinion lift.

This structure contains 111.7 cubic yards of concrete mixed in a 1:2½:5 proportion for plain and 1:2:4 proportion for reinforced concrete. The material in the concrete cost $9 per yard and the labor of concreting, excluding the excavation, was $2.29 per yard. Form lumber, on a basis of using it four times, cost 57 cents per yard. The excavation was in wet material, about one-half being cemented gravel. Water and cement were hauled one mile. The itemized cost is as follows:

Itemized cost data for low line lateral headgate.

Item.	Time or quantity.	Rate.	Amount.
Excavation:			
Foreman	50 hours	35 cents per hour	$17.50
Laborers	276 hours	25 cents per hour	69.00
Team	15 hours	50 cents per hour	7.50
Carpenters	5 hours	40 cents per hour	2.00
Material:			
Cement	133 barrels	$2.10 per barrel	279.30
Lumber	5,000 feet b. m	$5.50 per thousand	27.50
Sand	46 cubic yards	$4.80 per yard	220.80
Gravel	60 cubic yards	$6.70 per yard	402.00
Rock plums	42 cubic yards	$1 per yard	42.00
Gravel[1]	6 cubic yards	$1 per yard	6.00
Steel	160 pounds	2 cents per pound	3.20
Hauling			25.00
Concreting:			
Foreman	80 hours	40 cents per hour	32.00
Laborers	540 hours	25 cents per hour	135.00
Carpenters	160 hours	40 cents per hour	64.00
Helper	90 hours	27½ cents per hour	24.75
Concrete structure			1,357.55
Steel gate			100.00
Total cost of structure			1,457.55

[1] Screening some old gravel at site.

LATERAL HEADGATE, CALIFORNIA DEVELOPMENT CO., CALIFORNIA.

The engineers of the California Development Co. have designed standard plans for a reinforced concrete branch canal or lateral headgate. These plans are based on their experience of 10 years with wooden structures which these are designed to replace. The plans (fig. 8) show a gate with a minimum amount of concrete, heavily reinforced with steel to give the required strength. Unusual local conditions render great economy in concrete necessary in this region, as it costs as high as $48 per cubic yard. For this reason much time was spent in making a theoretically economic design. The form work would be relatively expensive for this structure, and in adapting the plans for a region where unit cost of concrete would not be so great the cost of forms may be reduced by altering the plans slightly. For instance, the division walls, now made of reinforced posts braced by similar members, could be made solid pier walls; the arched supports for the operating platform might be made slightly heavier of a reinforced rectangular-section slab; the counterfort walls under the front wings might slope directly from the upper edge to the floor, omitting the reentrant angle at the back.

The cut-off walls of this gate are of wooden sheet piling extending 12 feet into the bed of the canals. In adapting the plans, light concrete cut-off walls may be used. The depth would be determined by local conditions. For a canal well lined with cobblestones, therefore not in danger from erosion below the gate, a very shallow cut-off will suffice. A good anchorage already is secured by the weight of earth filling on the floor outside the walls and wings.

The girdered floor and the counterfort supports to the side and wing walls are features which may be adopted to advantage in the design of other gates. The girders and counterforts are reinforced to take the tension, thus enabling the intervening slabs to be made much lighter than if the girders and counterforts were omitted.

The shutters are of wood, constructed so that the main regulation is effected with flashboards, but a similar board is attached to the lower end of a stem so that the whole panel may be lifted as a single unit by a rack-and-pinion or other lifting device. This allows the water to be delivered either under or over the shutter or both. The plans shown are for a 3-bay gate, while the bill of material includes quantities for 3, 4, 5, and 7 bay structures.

The development company delivers 30 to 150 second-feet of water through these gates to the branch canals or laterals of the mutual water companies of the Imperial Valley, who purchase water by wholesale from the development company. All structures below the headgate in the lateral are owned and operated by the mutual companies.

Most of these gates are not calibrated nor is any attempt now made to use a standard formula for discharge through them, as the silt changes conditions quite rapidly, but current-meter measurements in

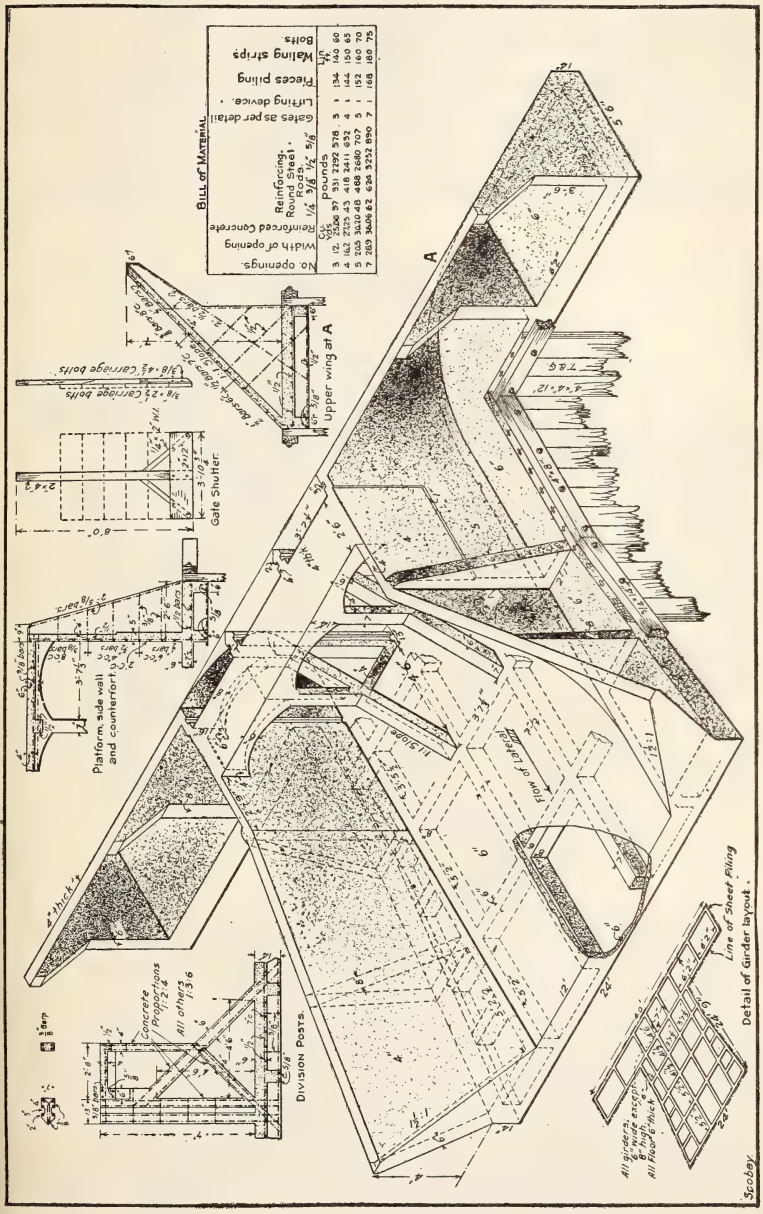


FIG. 8.—Branch canal or lateral headgate, California Development Co.

the canals below the gates, in some cases made several times a day, are made the basis of the charge for water against the mutual companies.

"A"-FRAME GATES.

A great many of the wooden lateral and check gates of the West have utilized the "A" frame in the setting of all posts and braces in the main channel of the flume forming the body of the structure.

The gross opening between side walls is broken up into bays by "A" frames embracing the guides for the shutters and the necessary braces to support the closed shutters. These frames also carry the operating platform or footwalk which acts as a strut in taking the

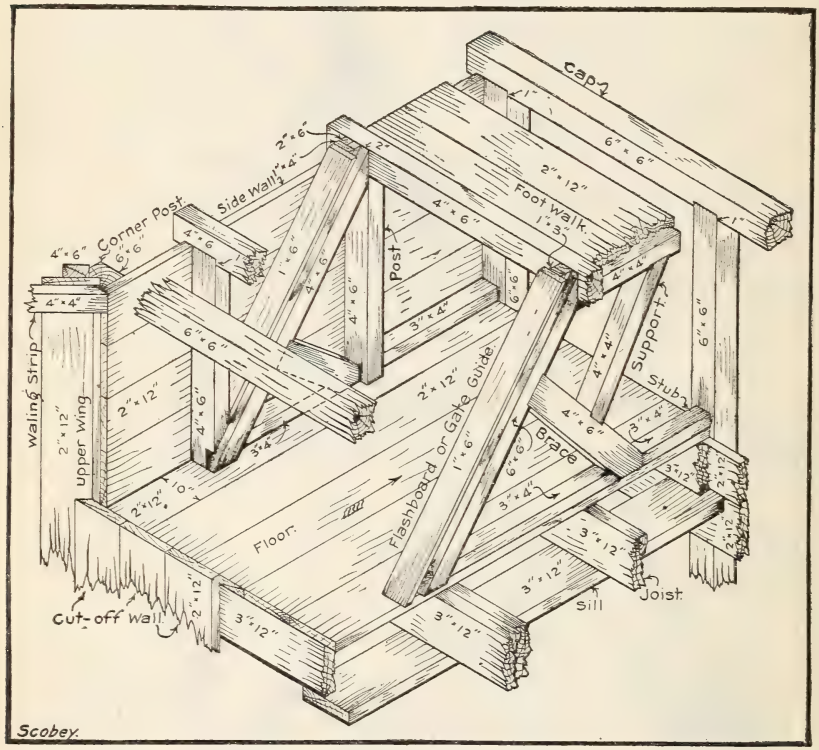


FIG. 9.—A typical "A" frame construction for headgate or checkgate as connected to drop, California Development Co., California.

thrust of the side walls and helps to maintain the spacing of the frames at the top. A typical construction of the frames and details of the general arrangement of members are shown in figure 9. The pressure of the water is transmitted downward to the floor, braces being set normal to the gate face and bearing against stubs. The larger structures have the floor spiked to joists which rest on mud sills as shown in figure 9. Small ones have the floor spiked direct to the sills. For such gates the braces go through the floor and are spiked to the sill. The "A" frames against the side walls are modi-

fied. The top of the gate guide rests against the top of a side post and the brace is carried from the angle between the floor and the bottom of the post up to the gate guide and at right angles to the latter.

The sheeting of the wings and cut-offs usually is set vertical and spiked or bolted through a waling strip. On small gates this sheeting is made of a single thickness. On large ones it is made triple thickness, each set of three boards being spiked together. The middle board is offset so as to form a tongue-and-groove joint. This "Wakefield" piling, as it is called, may then be driven with a maul or light pile hammer. The lower end of each piling is slightly sharpened at the exposed edge. This causes it to crowd closely to the preceding pile and make a tight joint.

The depth to which it was necessary to carry the cut-offs depends a great deal on the height to which the water is to be held up by the structure. If the water above and below the gate will be on approximately the same level, say within 1 or 2 feet, then it is not necessary to go more than one-half the depth below grade that the side walls extend above grade, but if more than that amount of pressure is developed the wings and cut-offs should extend as far below grade as the side walls do above.

High side walls that are separated too far to carry caps as struts are braced diagonally from the floor at about the line of the first division wall. High "A" frames have several diagonal braces, with horizontal sashes to prevent buckling.

The "A" frame catches trash easily and the water pounds violently if under much pressure, but both these defects may be much remedied by sheeting all the "A" frames on both sides with light boards. If used as a simple lateral headgate or check the upper and lower wings and cut-offs are identical, but if there is a drop in the grade line at the structure the lower posts are carried to the bottom of the water cushion and sheeted horizontally on the earth side as shown in figure 9.

DELIVERY GATES.

The same general discussion applies to delivery gates as to lateral gates. In addition it is generally necessary to have some form of locking device. Many companies place a device such as this on all gates, but do not use it unless it is found that the consumer under the delivery gate is abusing the confidence placed in him. In deciding upon a locking device for a delivery gate the designer must know the system of delivery of water. Some companies allow the consumer to shut the gate after he has received what water he wishes for that particular irrigation. For such a consumer a lock must be used which permits the gate to be opened to a certain point, determined by the position of the lock, but permits the gate shutter to

be closed at will. Most of the locks on standard sheet-steel gates are of this pattern. Other companies do not allow their consumers either to open or close the delivery gates. For such a gate there must be a positive lock which holds the gate shutter in the set position as determined by the ditch tender.

As stated before, water issuing under a gate shutter may be held more nearly constant than that passing over a crest. On the other hand, the amount of water delivered may be altered by the consumer in spite of locks if the orifice is submerged. If the consumer has a division box located close to the gate and the conditions of grade and velocity of water in the various ditches leading from this division box are such that the same amount of water in the head ditch flows away more rapidly in one direction than in another, then the back water against the delivery gate, and consequently the amount of water passing the gate, may be altered by the consumer by shifting the slides in his division box. This condition does not hold if the water issues under a delivery gate shutter into the open air, as there is no back water to be influenced by the consumer. An open-air delivery is possible only where there is sufficient difference in elevation between the canal and the head ditch to sacrifice some of it so as to secure the result desired.

DELIVERY GATE, CALIFORNIA DEVELOPMENT CO., CALIFORNIA.

Figure 10 shows a good example of economical design for a reinforced concrete delivery box of the open-culvert form. Water is diverted from a permanent canal where failure would cause much damage, aside from the immediate cost of replacement so that the upper wing walls extend farther into the bank than might be necessary for most installations of this sort. It is to be noted that the slots for the gate are placed slightly in front of the foot slab. The reinforcement does not extend down into the cut-off wall, the latter being used solely for the purpose of stopping seepage water.

This gate was built in the fall of 1910. The 7.6 cubic yards of concrete is a one to seven proportion of cement and gravel. A small concrete pedestal is bolted in the four holes shown on the top of the operating platform and to this pedestal is bolted the lever-lifting device for the rack-and-pinion lift. The cast-iron rack is bolted to the back of the gate stem.

RADIAL DELIVERY GATE, TURLOCK IRRIGATION DISTRICT, CALIFORNIA.

The deliveries to the consumers from the main laterals of the Turlock irrigation district are now being made through simple concrete-box structures regulated with wooden radial gates. Plate VIII,

figure 2, shows one of these gates before the canal bank has been completed. The roofing over the box will serve as a bridge. The wings of these gates extend at right angles to the flume a distance equal to the height of the flume. The upper wings and the cut-off wall under the upper end of the floor extend 2 feet below the floor, as a rule, but this dimension is adjusted to suit local conditions. The flume is 12 feet long, 4 feet or more high, and between 4 and 10 feet wide. The radial gate face is made of a double thickness of 1-inch redwood, the wooden radial arms carrying the thrust of the water from near the center of pressure on the gate when the canal is full to the 4-inch galvanized iron pipe axle extending across the flume

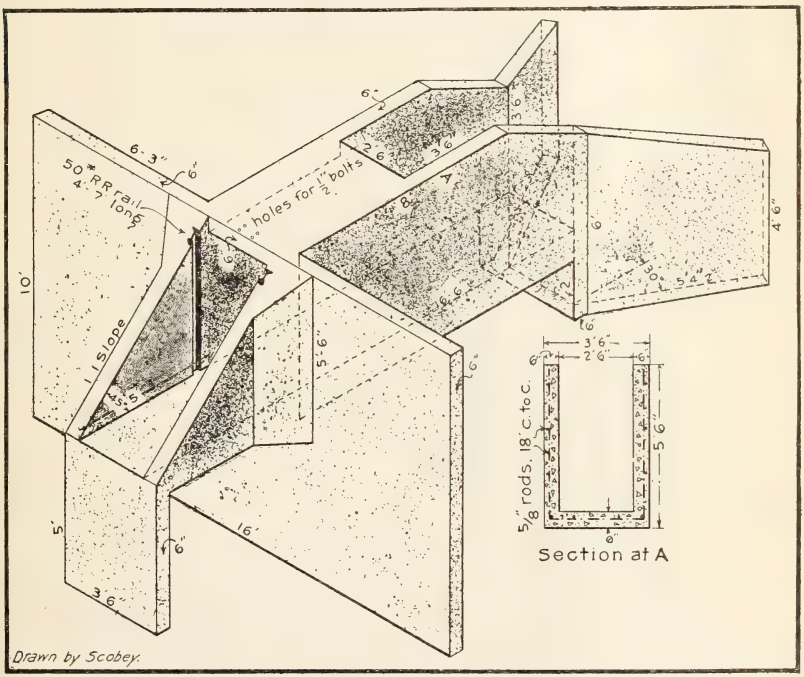


FIG. 10.—Reinforced concrete delivery gate from main canal, California Development Co., California.

about 2 feet in front of the rear end of the flume. This gate is more easily lifted when the water is in the canal than when there is no water, as the hydraulic pressure thrusts the gate against the axle and tends to float the gate. An iron bar with a handle at the free end is attached to the gate so that the latter may be lifted easily and locked in position by locking the bar over a hasp loop.

This type of construction might be readily adapted to lateral and even branch canal gates, as the forms are extremely simple, yet the structure is remarkably efficient.

TYPICAL TUBE DELIVERY WITH IRON GATES.

In the extensively irrigated region around Greeley and Fort Collins, and in the Arkansas Valley, in Colorado, a particular type of delivery gate has been used for a number of years and its use is spreading gradually to other States of the West. This is essentially a tube through the bank, with a cast-iron or sheet-iron gate at the canal end. Figure 11 shows this type of gate as used by one of the companies in northern Colorado. After a careful study of a great many installations of this type it is believed that the gate set at an angle of 75° with the pipe line gives the best results. This

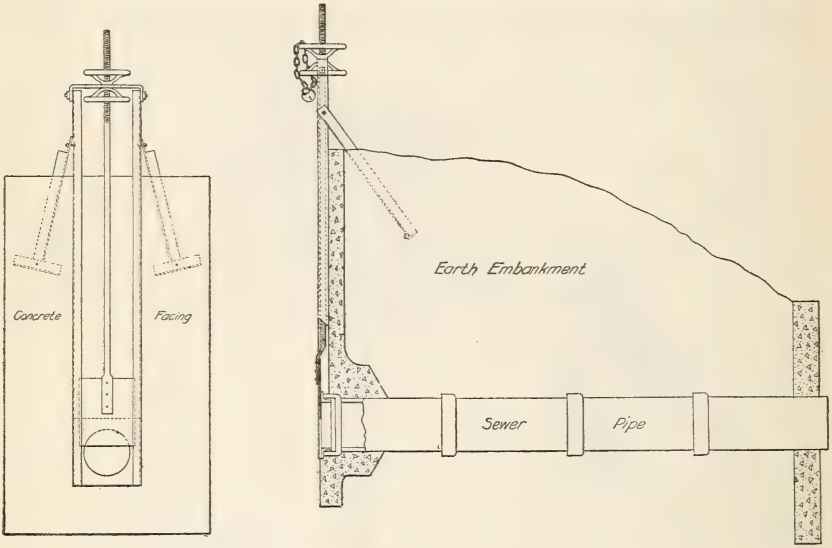


FIG. 11.—Tube delivery used by North Poudre Irrigation Co., Colorado.

slope will agree quite closely with the slope assumed by the banks of canals which have been in service for years, becoming overhung with grass and weeds. This slope allows a light concrete or masonry face to rest against the bank, more as a lining around the pipe opening than as a retaining wall, which it would be if the face were made vertical.

If the centers of the gates delivering water from above the same check all are set at the same elevation, and the grade of the pipe outlets is made the same, then all the deliveries will vary in approximately the same proportion when the head changes.

If it is not desirable to use check gates and hold the water against the delivery gates, then the latter should be set so that the bottoms of the tubes are approximately level with the bottom of the canal. Various grades are used for the laying of the pipes, but if the topog-

raphy of the country permits, a grade of about 1½ inches to the rod, or about 9 inches to 100 feet, is desirable. As a rule, the pipe tubes are 20 to 30 feet long.

The concrete or masonry face in which the gate is set should extend 1 to 3 feet below the bottom of the tube, between 2 and 5 feet on either side, and at the top from 1 foot to above the surface of water in the canal when the latter is running to capacity. In new construction where there is little or no vegetation to prevent erosion, or in light soil with relatively high velocities in the canal, the larger face should be used, but where a gate is being installed in an old well-set canal, with the banks well sodded and the permanent side of the canal well established, the smaller dimensions may be used safely. Such questions as these must always be finally determined on the ground.

The most difficult question and the one that must be settled satisfactorily in order to keep down maintenance charges is the general position of the face and iron gate. This is not so hard to determine on old ditches, but most construction is done at a time when the canal banks have not yet assumed their permanent form, and the tendency is to place the gate face snugly back in the bank so that a recess results when the banks become set. Here a quiet pool is formed where much silt is deposited, requiring a great deal of cleaning in addition to the annual cleaning of the system. This construction usually results in keeping down the initial cost to the extent of saving one or two joints of pipe, but the maintenance charges more than make up for the amount saved.

When a new gate is installed in an old canal, the face and gate should be set at such a point that the bank of the canal is disturbed as little as possible, as any irregularities in the bank cause the deposition of silt at some place near by. All things being considered, it probably is better to install the face too far into the canal rather than not far enough.

The construction at the outlet end of the tube is governed by many of the same conditions that held for the other end. A delivery from an old canal into a well-sodded head ditch will require little or no concrete or other protection around the outlet end of the pipe, but a delivery into a raw earth channel should be protected by concrete or rock riprap.

The picture shown in Plate VIII, figure 3, was taken at a time when practically all the water was out of the canal and the clean condition in front of the gates indicates that the position of the masonry face is about right with relation to the general bank of the canal. In this installation it is noticed that the face is set too far into the canal rather than not far enough, as is usually the case.

The average cost of vitrified-clay deliveries with iron gates, as given by the chief engineer of the Holbrook irrigation district, near La Junta, Colo., is as follows: 8-inch pipe and gate, $27.70; 10-inch, $30; 12-inch, $35, 15-inch, $40.

DELIVERY GATE, SUNNYSIDE UNIT OF YAKIMA PROJECT, UNITED STATES RECLAMATION SERVICE, WASHINGTON.

The intake of a tube delivery or turnout gate unless set at just the right point is a great source of annoyance because of the silt and sand that gathers just in front of the gate when it is not in use. To obviate this condition, remove the tendency of the eddies in the entering water to scour the canal bank, and preserve as much as possible the unbroken side of the canal the United States Reclamation Serv-

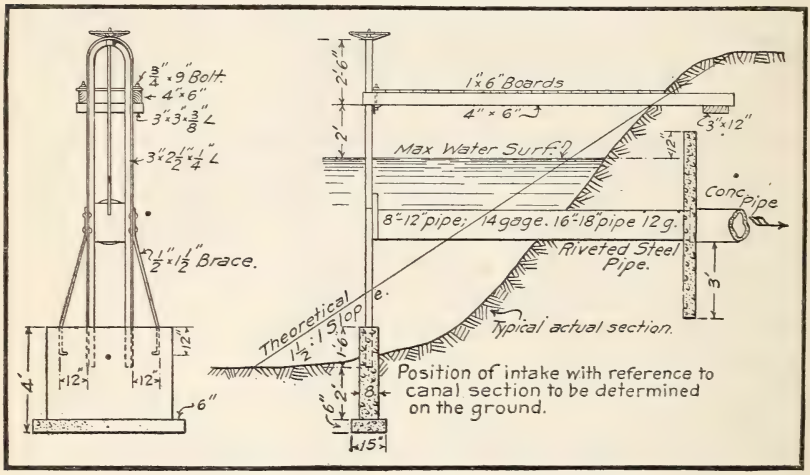

3/4" x 9" Bolt
4" x 6"
3" x 3" x 3/8" ∠
3" x 2 1/2" x 1/4" ∠
1/2" x 1 1/2" Brace.
1" x 6" Boards
4" x 6"
3" x 12"
Max Water Surface
Conc. pipe
8"-12" pipe; 14 gage. 16"-18" pipe 12 g.
Riveted Steel Pipe.
Theoretical slope 1 1/2 : 1
Typical actual section.
Position of intake with reference to canal section to be determined on the ground.

FIG. 12.—Tube delivery extending into canal, Sunnyside unit, Yakima project, United States Reclamation Service.

ice is using a system of installation on the Sunnyside Canal in Washington which is very favorable to canal operation.

A riveted-steel pipe extends out into the water of the canal, as shown in figure 12, being supported at the front end by the gate standards which are carried down to a footing wall. The steel pipe is carried a short distance into the bank where it meets a concrete pipe in a concrete cut-off collar. This installation does away with a wood or concrete face slab at the entrance to a tube outlet when set flush with the bank and also removes the opening in the tube from danger of becoming clogged with silt and trash.

The only place that comes to the writer's mind where such a construction, cost permitting, might not be used, would be where it is necessary to dredge silt out of the canal or lateral. In such cases

the dredge would be liable to tear out the gate end of the construction.

Various modifications in the kind of pipe will suggest themselves, depending on the relative cost and the use. The principle will be the same.

CHECK GATES.

In a flat country where there is very little fall to the laterals and to the head ditches leading from them, it may be necessary to raise the water at the point of diversion from the canal and raise the upper end of the diverting ditch above the surface of the surrounding country. In this manner grade enough is developed for the diverted water to maintain some semblance of velocity. This condition is met by building a check gate or "check," as it commonly is called, across the canal supplying the water, below the lateral or delivery headgate. This check serves as a bulkhead to check up or completely stop the water in the canal and turn it through the side gate.

Some companies maintain a system of deliveries, especially in the smaller canals and laterals, by which the ditch tender makes the first delivery to the consumer farthest down the canal. When his run of water is completed it is desired to turn all the water to the consumer next above him. This is accomplished by the use of checks in the supplying canal below the points of diversion to the consumers.

Another use for this device is found in the latter part of the season, when there is comparatively little water in the canals. The vents in the check are closed enough so that the level of the water above them is raised and it is possible to deliver the desired volume of water.

Where the supply of water in the canal from which water is being diverted is subject to great fluctuation, it is possible to assure the level of the water always reaching a known height at least by the insertion of flashboards in a check. This is sometimes accomplished by closing some of the panels with flashboards and some with solid gate shutters, allowing water to flow under the latter. The level of the water above a check which is discharging water over a crest is held more nearly constant in spite of fluctuations than is possible in a check where the water is discharged under gate shutters, for the reason that the discharge over the crest varies as the cube of the square root of the head on the crest, while the discharge through the openings under the shutter varies as the square root of the head over the opening. In other words, a given fluctuation in the supply will be more quickly cared for over a crest than through an orifice, and the elevation of the water will change less.

This is a rather important question in the operation of a system, so a case in point may not be out of order. Assume a discharge of 3.5 second-feet to be passed through a check. With a submerged ori-

fice 3 inches high and 4 feet wide the pressure head required will be about 6 inches. If this discharge be increased to 5.5 second-feet, then the pressure head on the same opening will be about 14 inches. If the same volume of water is passing over a crest—giving approximate weir conditions—of the same width (4 feet), then the head on the weir will increase only from 5 to about 6½ inches. Therefore this given fluctuation raised the level of the water in front of a given submerged orifice 8 inches, while the same amount of fluctuation raised the level on a crest but 1½ inches.

The great factor against securing all of the control of the water above a check by means of crest discharge is that the stilled water tends to cause the deposit of all sedimentary matter in the water, and if the check is not "pulled" regularly this deposit will become the cause of trouble and expense. On the other hand, water discharging through an undershot gate issues from the structure in a very turbulent condition and tends to cause damage by erosion of the banks below the gate. In the opinion of the writer the form of shutter shown in figure 8 (p. 37) gives the best general solution for a cheap check shutter. The loose flashboards allow for crest regulation, and the fact that the shutter may be lifted as a unit by the stem attached to the lowest board of the series allows the opening to be "pulled" and the silt scoured out. This operation is not tedious or so liable to be shirked as is the case if ordinary flashboards are used.

The elevation of the crests of various checks on a system is a matter of great importance. It is usual to design the extreme top of the structure at least 6 inches above the maximum height to which water is to be checked. Some companies mark a line on the structure as the limit of safe operation, because, as a rule, the levees above the check are made to conform to the height of the check or, as a matter of safety, 6 inches above the check.

In an uneven flat country the cost of developing in detail contours of small interval is so great and so much time is necessary to accomplish this that it is a very common sight in such irrigated regions to see a great number of checks which have been built up a foot or two in order to check up the water to reach high knolls which were not noticed during the original construction. On the other hand, it is quite common to see checks on which the high-water mark shows that there was more material put into the structure than was necessary. In other words, a check gate is one of the structures of which a careful study must be made in order to determine whether it would not be better to install wood in the initial construction and replace with concrete when the wood decays. By this time the ditch tenders handling this structure will know exactly what

height the permanent gate should reach, and it can be designed accordingly. If concrete is used in the beginning, then it is difficult to add to the height without great expense and a patched appearance, and if the structure is already too high, then the extra material is wasted.

Most checks are for the sole purpose of controlling the level of the water above the structure, and the question of tightness does not enter into their design. However, if for any reason it is desired that all the water be stopped at a check and delivered to a side gate, then the shutters must be made tight by closer joints, tar or other roofing paper, or in some such manner.

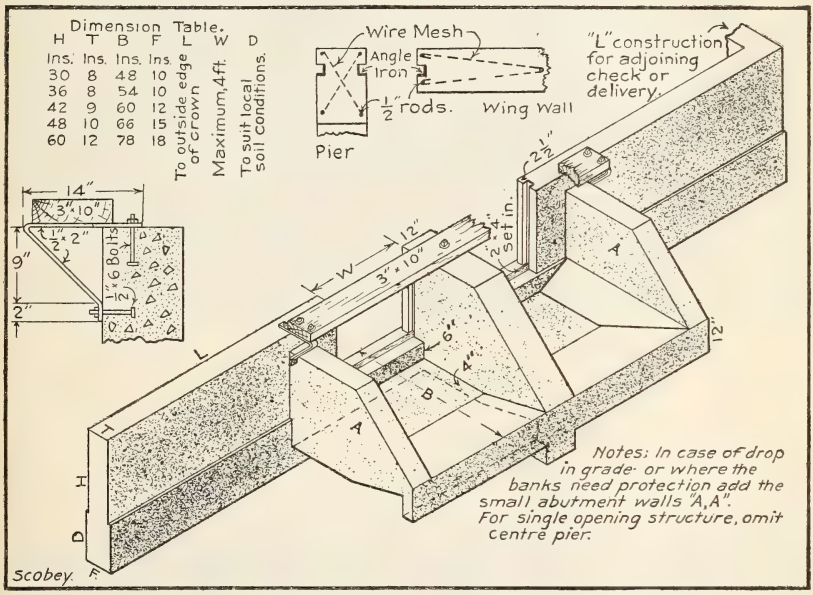


FIG. 13.—Concrete check, lateral headgate or delivery gate, Sacramento Valley Irrigation Co., California.

CHECK GATES, SACRAMENTO VALLEY IRRIGATION CO., CALIFORNIA.

The Sacramento Valley Irrigation Co. has adopted a set of standard plans which may be used in many other parts of the West. The check-gate structure shown in figure 13 can be used also as a lateral headgate or a delivery gate. In fact this is done by the simple L construction which is so well adapted to a combination of check and delivery. The general construction of this gate is adapted either to flashboards or a stem gate. The latter is used most commonly by this company. As shown on the detail view in Plate I, *i*, this stem permits of holes through it far below the top of the shutter without causing leakage through the latter, and it is not necessary

for the standards to be raised above the crest of the wing walls in order to secure elevation sufficient to raise the shutter.

It will be noted from the plans that this is practically a sheet structure with a small basin attached to the back to withstand the erosion and pound of the falling water. The buttress construction of this basin also braces the front walls. The plans show a double 3-foot opening check with small buttress walls at the sides of the basin, used where there is drop in grade or the material of the banks requires protection. For double openings the middle buttress wall is not omitted, even though the conditions do not require the smaller side buttresses. The constant dimensions for all this class of structures are given in figures, while the variable ones are lettered and refer to the figures in the table under the letter given.

Plate IX, figure 1, shows a combination of check and delivery structures as used by the Sacramento Valley Irrigation Co. Note the inset panel cast in the concrete, upon which the number of the structure is carried. One gate has been numbered and the panel on another gate is shown in blank.

CHECK GATES, IMPERIAL WATER CO. NO. 1, CALIFORNIA.

Plate IX, figure 2, shows a typical wooden check as used on the main laterals, carrying 30 to 150 second-feet. This particular gate has three bays, the two on the outside regulated by flashboards and the middle one by a simple slide gate, with holes for a pin, which may be locked. The upper and lower wings are identical, as are the cut-off walls at both ends of the floor. Wings and cut-offs extend as far below grade as the side walls extend above. Replacements on a well-set ditch may be modified to the extent of making the depth of these walls about one-half the height of the side walls above grade. The floor usually is set 1 foot below the bottom grade line. The companies in the Imperial Valley use 1-inch redwood for the sheeting on this class of structures, while the posts and sills are made either of redwood or Oregon pine (Douglas fir). These gates last 6 to 10 years.

Note that the posts are all on the waterside. They pass through the floor and are spiked direct to the sills. Diagonal braces extend from the upper ends of the guideposts at both ends of the slide gate down to the foot of the posts shown under the lower cap. No battens are used, as this silted water closes all cracks rapidly, and in addition the gates are puddled in most thoroughly before water is run commercially. In the foreground of the picture is seen a good example of the use of brush riprap, described on page 11 for the protection against eddying water. The structures of this company are numbered with an ordinary, cheap grade of metal house numbers, which remain bright and are easily set on a wooden gate.

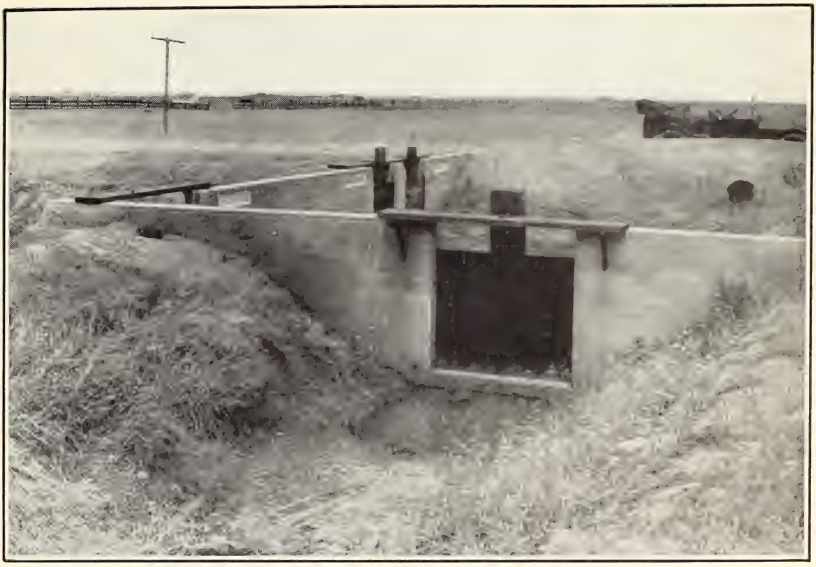


FIG. 1.—COMBINATION CHECK AND DELIVERY STRUCTURE, SACRAMENTO VALLEY IRRIGATION CO., CALIFORNIA.

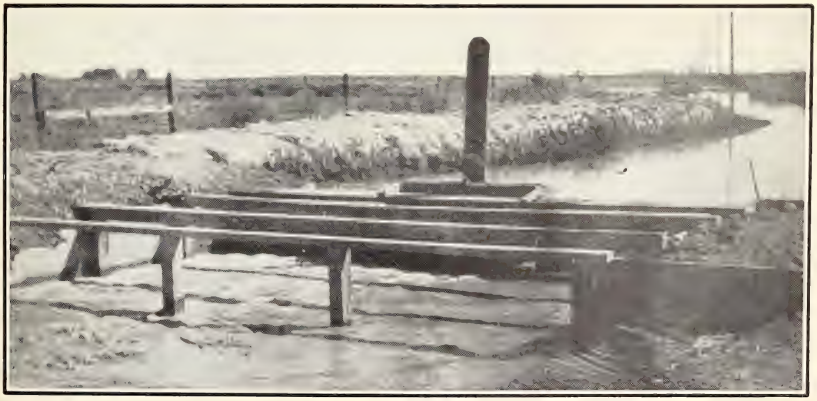


FIG. 2.—WOODEN CHECK GATE, IMPERIAL WATER CO., NO. 1, CALIFORNIA.

FIG. 1.—AUTOMATIC CHECK GATE, TURLOCK IRRIGATION DISTRICT, CALIFORNIA.

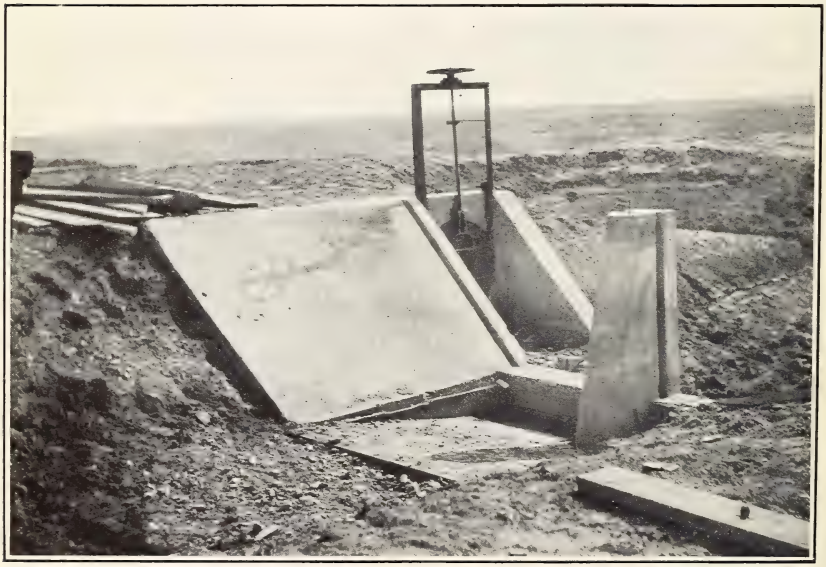


FIG. 2.—COMBINED CHECK AND DELIVERY STRUCTURE, ROCK CREEK CONSERVATION CO., WYOMING.

AUTOMATIC CHECK GATE, TURLOCK IRRIGATION DISTRICT.

The Turlock irrigation district of California is using for all new constructions and all replacements of worn-out wooden checks a patented automatic gate, which holds the water above it to a constant level (fig. 14).

The essential features of this check are: A wooden-faced gate with wood or iron radial arms attached to an axle shaft; a concrete well cast in one wing of the structure, with an inlet pipe from the water whose level it is desired to hold constant; an outlet pipe emerging from near the bottom of the well into the water below the check gate. The level of the water into which the outlet pipe discharges must be lower than the level of the water which the device is to hold constant; a tank float in the well (D) (Pl. X, fig. 1), hung by a chain to the end A of lever 2, which is connected to lever 1 at B. To the end C of lever 1 is attached the chain lifting the radial gate. The fulcrums of the levers are placed at the centers. A counterweight (E) of concrete is hung from the intersection of the two levers at B. The tank is partially filled with water, the amount adjusted to fit each gate after it is in operation.

The operation of the gate is as follows: Assuming there is no water in the canal and the gate (G) is shut, the free end of the inlet pipe (P) is placed at the level to which it is desired to hold the water, the free end of the outlet pipe being placed lower than the opening in the inlet pipe. As the water comes down the canal the closed gate causes it to rise until it enters the well through the inlet pipe. As it rises in the well the weighted bucket or tank is floated, the levers at B are both pulled down by the counterweight, and the gate lifted, allowing water to pass under it, establishing equilibrium again. The water in the well flows out slowly through the outlet pipe, tending to lower the tank, raise the weight at B, lower the gate, raise water above the gate which flows into the inlet pipe, and thus keep up a circulation of water in the well. It requires about an 8-inch head of water on the gate for it to adjust automatically.

If water has been running in the canal several days, always maintained at the same elevation, and an unexpected rise in the water occurs, the depth of water above the gate increases rapidly, submerging the inlet pipe and quickly raising the water in the well, which as quickly lifts the float, lowers the counterweight, and raises the gate to allow the unexpected volume of water to pass by until equilibrium is again established, always at the level of the opening to the inlet pipe.

In the same way, if the volume in the canal is diminished, the water level falls below the opening in the inlet pipe, the water in the well lowers gradually through the outlet pipe, the tank settles

down, raising the counterweight and shutting the gate until the water is sufficiently checked to enter the inlet pipe again.

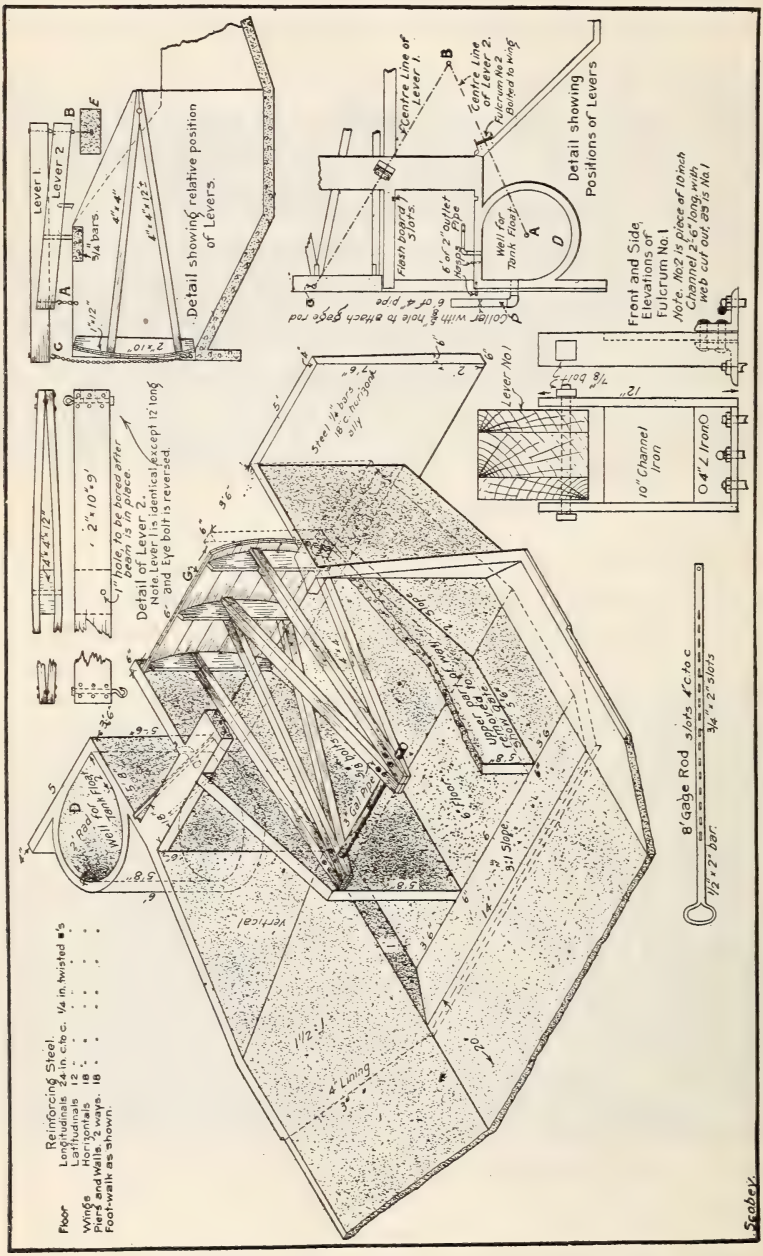

Detail showing relative position of Levers.
Lever 1
Lever 2
Detail showing Positions of Levers
Front and Side Elevations of Fulcrum No. 1
Detail of Lever 2.
Note. Lever 1 is identical, except 12' long
Reinforcing Steel
Floor Longitudinals 24 in. c. to c. ¼ in. twisted ⅝'s
Transverse 12 " " " "
Wings Horizontals 18 " " " "
Piers and Walls 2 ways. 18 " " " "
Foot-walk as shown.
8' Gage Rod 3 slots 4' c. to c.
Well for Tank Float
Float Board 3 slots
6" of 2" Outlet Pipe
Collar with hole to attach Gage rod
6" of 4" pipe
Fulcrum No 2 Bolted to wing
Centre Line of Lever 1.
Centre Line of Lever 2.
Lever No 1
10" Channel Iron
4" Lining
1½:1
3:1 Slope
Vertical
Seaber

FIG. 14.—Automatic check drop on lateral of Turlock irrigation district.

Numerous modifications of this principle are practicable. Where it is desired that a certain fixed volume enter the headgate of a canal,

regardless of moderate fluctuations in the supplying stream, the inlet pipe is set below the headgate and the outlet carried to a lower level. This is possible only where a diversion dam of some sort is used and the outlet pipe discharges into the stream below the diversion dam, and where this water is lower than the proposed water in the canal below the gate. Only one lever is used, connected to the gate at one end and the counterweighted tank at the other. When more water than is desired enters the canal it fills the well through the inlet pipe, raises the tank, and lowers the gate until equilibrium is established. If the supply falls then the water in the well gradually passes out through the outlet pipe, the tank falls, raising the gate, and thus allowing more water to enter.

The operation of these gates in the Turlock district is practically instantaneous and allows the canals to be run with larger heads of water than would otherwise be safe.

Where the level of the water, and consequently the volume, in a side lateral or consumer's delivery is to be held constant the inlet pipe is placed at the desired level in the lateral, but the double system of levers operates on the check gate as before. This system could be used to insure uniform deliveries to consumers and would protect the banks above the check also, because the rising water above the check would increase the delivery to the side lateral, flow into the well, raise the tank, lower the counterweight, and lift the check gate sufficiently for the excess water to pass on down the canal.

The particular structure shown in figure 14 combines both an automatic check and a drop located on lateral No. 7, which carries about 200 second-feet of water. The height of the open ends of both inlet and outlet pipes may be adjusted, as they can be swung about on the threads of the elbows. About two-thirds of the way up these two pipes the gage rods are attached. The slots in the rods are slipped over staples set in the concrete walls near the top and padlocks through the staples over the bars lock the device.

The bucket or tank hanging in the well is made of No. 16 galvanized iron, 44 inches in diameter and 3 feet high, the top lapping over a $\frac{1}{2}$-inch round pipe stiffener and riveted thereto. Two straps of $\frac{1}{4}$ by $1\frac{1}{2}$ inch iron pass completely around the bucket at right angles to each other and are brought together 2 feet above the rim.

The concrete counterweight hung below the intersection of the lines of the two levers is of convenient shape and weighs about 300 pounds more than that portion of the gate to be lifted by it.

The automatic radial gate is built up of double 1-inch Oregon pine. Before being set in the concrete the ends of the pipe axle are bored and 12-inch pins thrust through them, which prevent the axle turning in the concrete.

Where the concrete is mixed by hand on structures like the one described, the Turlock district finds it costs $20 to $22 per cubic yard, while machine-mixed concrete on large structures runs about $13 per cubic yard. The mix used is one part cement to three parts sand and five parts broken stone. Cement costs $2.75 per barrel f. o. b. Turlock, and sand usually is close at hand. Stone costs $1.75 per cubic yard and the hauling 17 cents per mile per yard additional. The reinforcing bars cost 3¼ cents per pound at San Francisco. The total cost of a structure like the one in figure 14 is about $300.

Where a similar design is used for a simple check gate, a lateral headgate, or a drop of less than 2 feet, the pier walls are carried level on top, the slope being omitted, and the axle set 3 inches higher and 3 inches farther back from the face of the gate; also the lower 12 inches of the gate shutter is replaced by a 12-inch weir board. Where used as a waste gate or in any place where tightness is desirable the shutter is made water-tight by placing waterproof roofing paper between the two layers of the double face and rubber belting is placed at the edges.

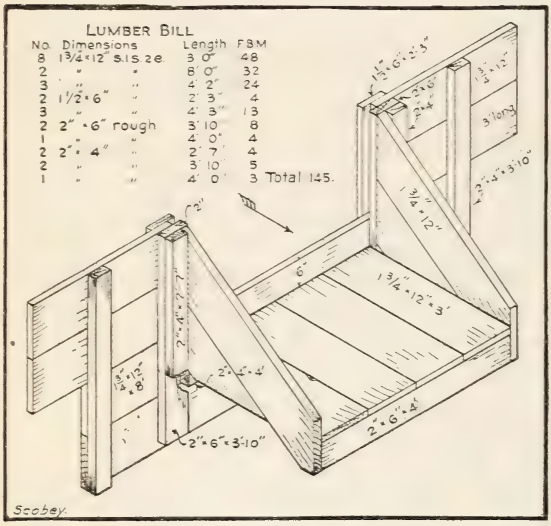


FIG. 15.—Sublateral check, Tieton unit, Yakima project, United States Reclamation Service.

SUBLATERAL CHECK, TIETON UNIT, YAKIMA PROJECT, UNITED STATES RECLAMATION SERVICE, WASHINGTON.

A check which is well adapted to withstand a fall of water behind it is shown in figure 15. It is used for small laterals, and is adapted to the temporary construction which contemplates a permanent structure similar to the one shown in figure 13, page 47.

COMBINED CHECK AND DELIVERY STRUCTURE, ROCK CREEK CONSERVATION CO., WYOMING.

The "L" construction of check and delivery gates is well exemplified in the view (Pl. X, fig. 2) taken on one of the main laterals of the Rock Creek Conservation Co., in Wyoming.

The concrete and iron work is complete while the anchor-bolt to hold the wood foot plank, just back of the flashboard slots, is shown on top of the pier wall. The canal below the structure is lined for a short distance, sloping rapidly on the bottom to form a water cushion. A shallow cut-off wall extends vertically downward at the end of the lining to prevent undercutting of the eddying water. Sufficient cut-off should be provided under the flashboard sill and across the front of the turnout gate to prevent percolation and failure due to the hydraulic head developed when water is checked up. As shown the delivery gate is vertical. A more economical con-

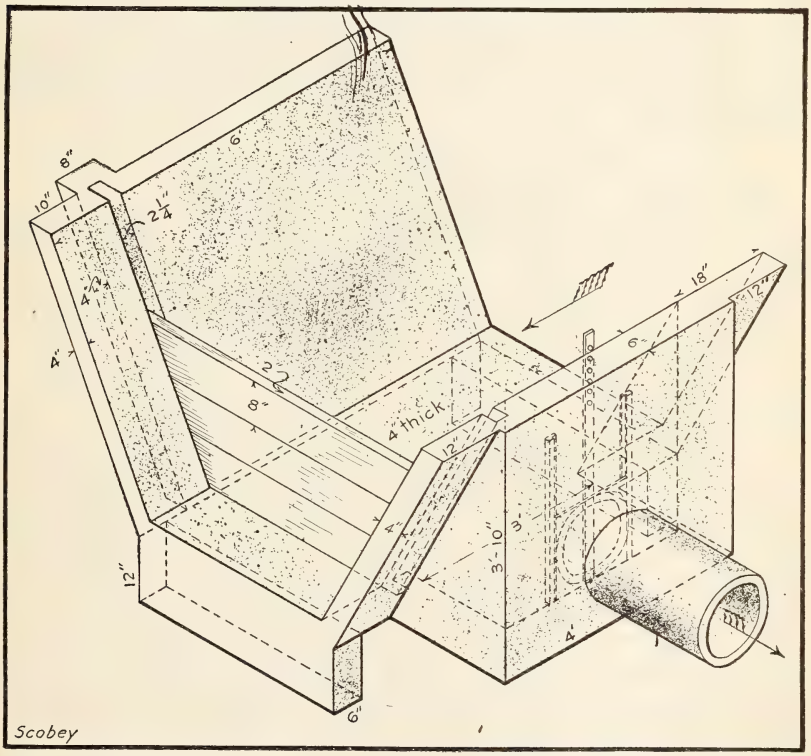


FIG. 16.—Combined check and delivery structure of Beaver Water & Irrigation Co., Colorado.

struction would be to use the 45° connection as manufactured and slope the gate to conform to the 1 to 1 slope of the lining below the check. This would remove the recess, in which silt will gather when the delivery gate is closed.

COMBINED CHECK AND DELIVERY GATE, BEAVER WATER & IRRIGATION CO., COLORADO.

A very economical, neat, and effective structure is used for the deliveries from small, open ditch channels of this company (fig. 16).

It amounts to a lined section of canal with a shallow cut-off wall at each end and a delivery tube through the bank, regulated by a sheet-iron gate. Débris is kept out of the delivery by a screen extending across the recess in which the gate is set. For most systems this screening would not be necessary. If the water in a lateral using this type of structure is to be checked up more than 2 feet above the bottom it would be well to extend the lined section farther down the channel and carry the lower cut-off deeper into the bed of the ditch. This depth will be determined in all cases by the material of the bed.

In adopting this plan a cheaper installation is made by omitting the recess for the gate shutter, allowing both banks of the lined section to slope uniformly to the bottom of the ditch. The gate shutter can be set on this slope, using the connections and gates as made by the manufacturers for a connection with a tube at 45° or 60° with the gate standards.

SAND GATES.

Some designers attempt to exclude the sand before it enters the canal by installing a sluice gate with a sill below the intake of the canal, adjoining the river gates on the downstream side, but as a rule the water is so agitated at the heading that only the heavier sand remains on the bottom and the lighter particles, whirling about in the water, are passed on through the gate to settle in the canal at some point lower down where the velocity is reduced to such an extent that the sand is no longer rolled along the bottom.

It is probably much better to install a separate sand structure far enough below the head of the canal so that the latter will have gained enough elevation over the bed of the stream to obtain a good flushing velocity, and scour out the sand deposit from time to time as water is available. If the water rights on the stream are such that there are other consumers on the stream below the sand gate entitled to water at all times, then an arrangement may be effected so that a surplus amount of water can be run and the sand gates left open throughout the season, returning the surplus water to the stream. Kansas recognizes this benefit by legislation in its favor.

THE SUMP GATE.

There are three general types of gates to remove the sand below the headgate of a canal system. The first consists of a sump connected to a discharge ditch or natural channel by gates located below the normal grade of the canal. This construction makes a combination sand and waste gate. Such a gate as this may be partly opened all the time or it may be closed completely except when a flushing head is available and then opened wide and all the water in the canal used for a short period to wash out the sand which has accumulated. The

crest of the gate shutters of this type of structure usually furnishes a good opportunity to waste excess water in the canal by simply adjusting the crest height of the closed gates to the water line deemed a safe elevation. The radial gate offers a good opportunity in this class of structures, the scouring action coming at the bottom where it is desired.

THE TRENCH GATE.

The second type is used only on small ditches and is a modification of the first. It consists of a channel or groove set in the floor of the ditch across the line of the latter. A sliding gate is set in the end of this channel, opening out through the lower bank. A check board or strip of iron is fastened to the floor of the ditch immediately below the channel. This serves to stop the sand and drop it into the channel, from which it is flushed by a continuous stream passing out through the gate. In the opinion of the writer it is best to build the channel across the bottom of the ditch at an angle, with the gate at the lower end. This would cause the filaments of current in the ditch to take the direction of the channel and help carry out the sand.

A sand gate in the South Boulder and Coal Creek Canal, a small ditch diverting water from South Boulder Creek at the town of El Dorado Springs, Colo., has a channel set in the bottom of a section of wooden flume, opening over the side of the ditch into the creek. This channel is about 5 inches wide and 6 inches deep, with a check board made of simple 2 by 4 inch lumber set on edge immediately below the lower edge of the channel. This channel is at right angles to the flume.

This type of gate is easily clogged with trash, the channel being so small that a little stick could effectually commence the clogging of the opening. This may be prevented by putting in a grating of bars, slanting very gradually up from the floor above the channel to the top of the check board. The gentle incline to the bars will cause débris to be pushed on over the check board rather than "glue" to the grate, while the sand is admitted readily between the bars.

THE "LAND" GATE.

The third type of sand gate, and the one commonly used in the Arkansas Valley of Colorado, was first built by Mr. Gordon Land, of Denver, Colo., and has been known as the Land gate. This structure is essentially a check and waste gate with a double floor above the check, the upper floor being on the normal grade of the canal, while the space between the floors is separated by ribs into ducts. These ribs carry the upper floor and are curved so that the

stalls between them guide the sand around into a direction at right angles to the flow in the canal and discharge it out through the waste gate forming an L with the check gate. One of these gates is included in the joint head works spoken of on page 14.

SAND GATE, MAXWELL LAND & IRRIGATION CO., MAXWELL, N. MEX.

After trying out a wooden structure, the Maxwell Land & Irrigation Co. has designed a concrete gate to eliminate the sand and coal dirt from its water, 700 feet below the river headgate. At this point an arroyo leads back into the river.

The canal, which is 32 feet wide on the bottom, carrying water 7 feet deep, with the top of the levees 3 feet above high-water mark, is lined with 6 inches of concrete for a distance of 400 feet above the gates. This lining (fig. 17) commences at the normal grade of the canal and slopes on a grade of 1 foot per 100 feet on the side next to the river and 3 inches per 100 feet on the other. This slope forms a long pit having a maximum depth of 4 feet directly in front of the gates, and it is expected that even a small head of water in the canal will effectually sluice out all silt deposited on the concrete lining. The end of the pit terminates in a vertical wall, crested with a rectangular weir, which serves the double purpose of deepening the pit by the height of the weir and giving an approximate measurement of the water in the canal, after the proper bottom-contraction conditions are effected by sluicing out the deposit above the weir.

The shutters are simple wooden slides with double stems separated by iron bolts and spreaders, on the principle of the one on Plate I, *f*. An iron-mounted lever 12 feet long gives a fast and effective lift when inserted under the bolts. The silt above such gates causes them to stick, and some lift is necessary which will jerk the gate, rather than to exert a steady pull. For this reason the lever is better than a screw lift.

Bids for the concrete construction varied from $3 to $3.60 per cubic yard, the company to furnish the material at the site. Bids on the excavation for the structure were 14 and 18 cents per yard. This will make the total cost of the concrete in place $10.50 to $11.25 per yard.

SAND AND WASTE GATE, AMITY CANAL, COLORADO.

One of the best examples of the modern construction and use of the "Land" sand gate is the concrete sand and waste gate installed on the Amity Canal by the Arkansas Valley Sugar-Beet & Irrigated Land Co. This structure (as shown on Plate XI, fig. 1) forms an L, one leg of which extends across the canal and acts as a check gate, while the other leg contains the openings of the sand ducts at

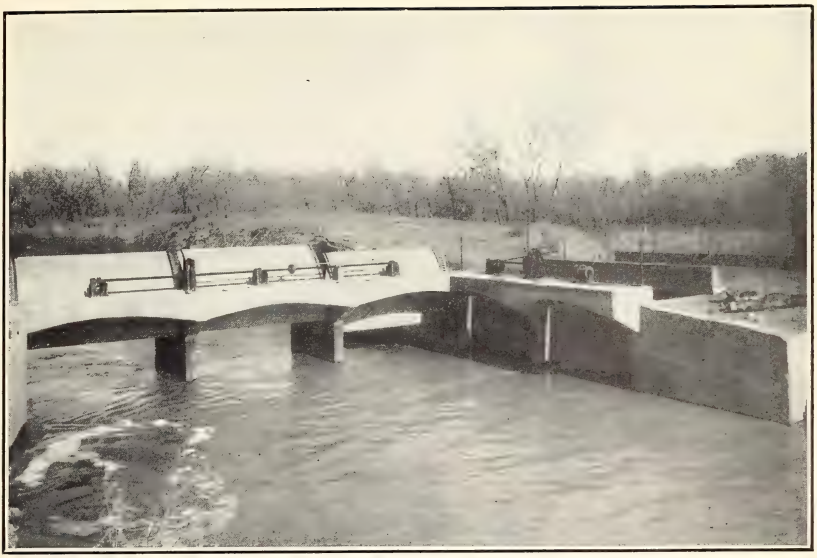


FIG. 1.—SAND AND WASTE GATE, AMITY CANAL, COLORADO.

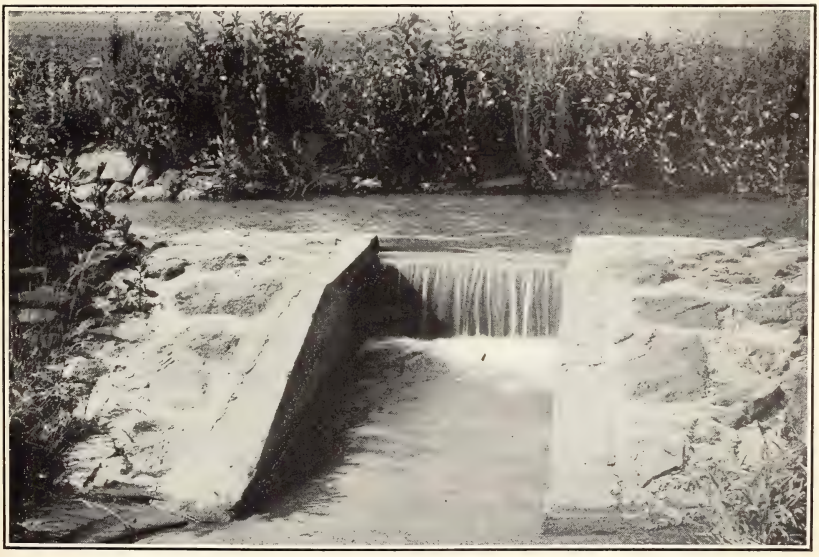
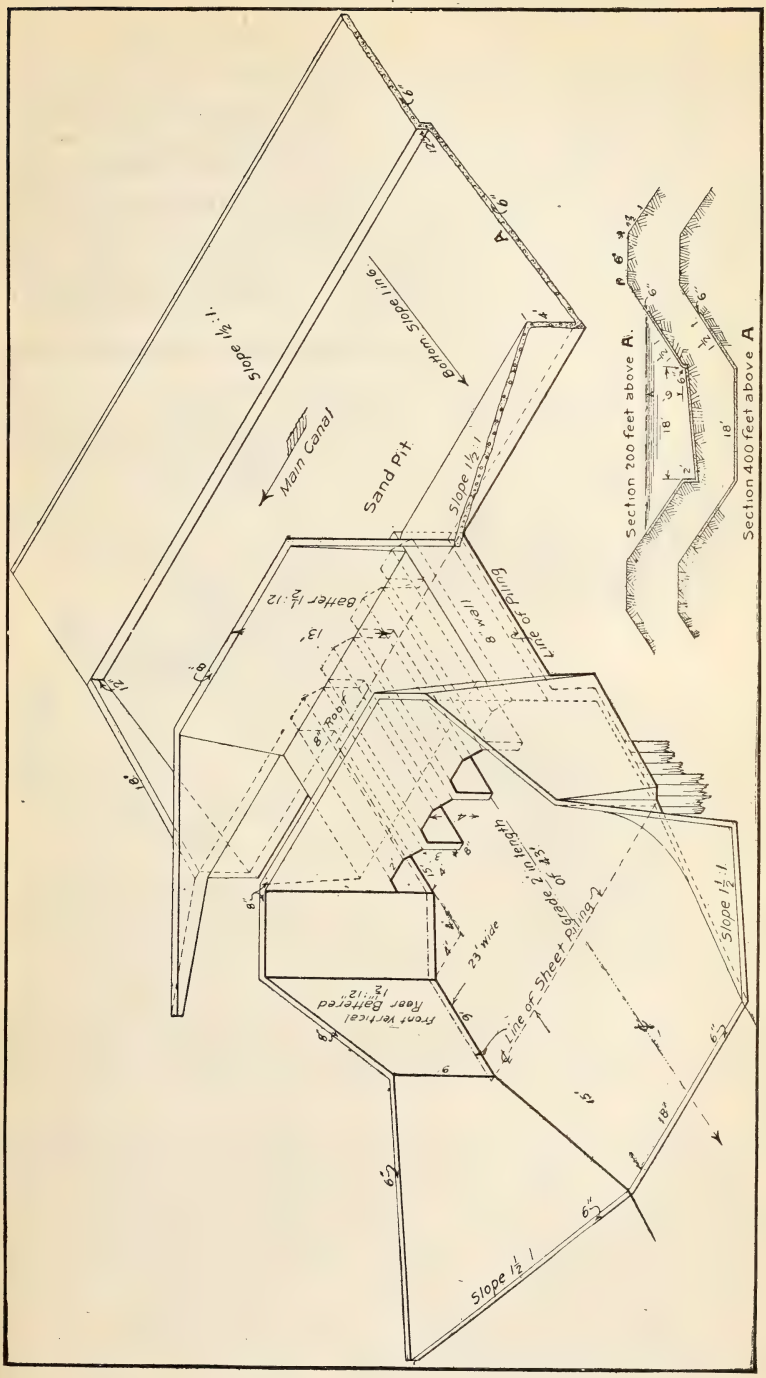


FIG. 2.—WASTE GATE ON SMALL LATERAL, YAKIMA PROJECT, UNITED STATES RECLAMATION SERVICE.

FIG. 1.—WASTE GATE ON LAKEVIEW IRRIGATION CO. CANAL, WYOMING.

FIG. 2.—WASTE GATE, TURLOCK IRRIGATION DISTRICT, CALIFORNIA.


Main Canal
Sand Pit
Bottom slope 1:16
Slope 1½:1
Slope 1½:1
Slope 1½:1
Slope 1½:1
Batter ½:12
Batter ½:12
Line of paving
8" wall
Section 200 feet above A.
Section 400 feet above A.
Front vertical floor Battered ½:12
Line of Sheet Piling
Gage of 43
23' wide
18'
15'
6½'
6½'
6½'
6½'
6'
6'
6

the bottom of one bay and also serves to waste excess water by raising the radial gates above the upper cover to the sand ducts.

The waste structure is designed to pass all the water the canal can carry to it; that is, 870 second-feet. The check structure consists of three 12-foot openings, regulated by radial gates attached to cables wound around small drums through worm-and-wheel leverage.

The distinctive feature of this structure, as explained under the general description of the "Land" sand gate, page 55, is the double floor with sand ducts between (fig. 18). On the assumption that most of the sand is close to the bottom, two distinct currents are in-

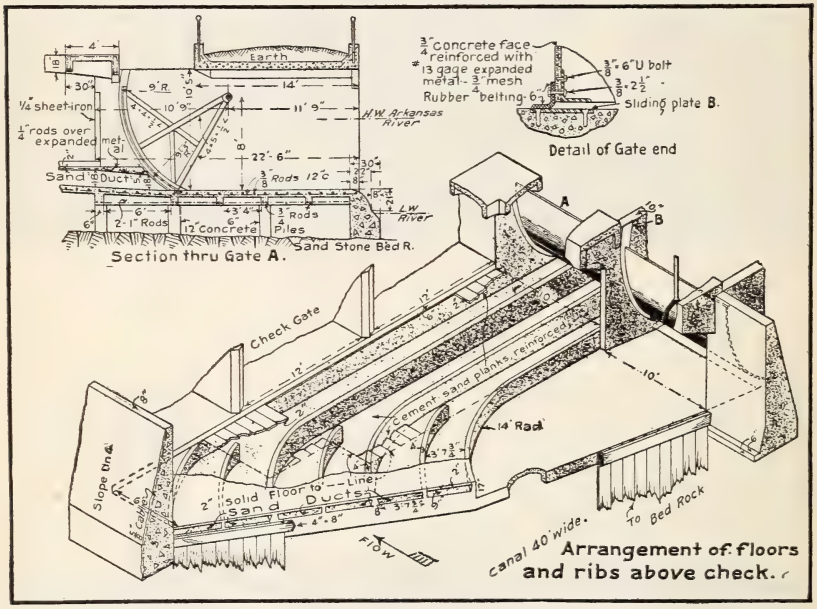


FIG. 18.—Portions of sand and waste gate on Amity Canal, Colorado.

duced in the canal by covering the ducts for some distance above the check gate. When the sand gate is open the steep grade of the ducts causes a high velocity, uninfluenced by any slow water above the floor.

In order to facilitate the cleaning of clogged ducts, a portion of the upper floor is made of reinforced cement mortar planks. The various ribs forming the ducts serve a double purpose. They not only support the upper floor, but divide the water under the upper floor into several streams so that the sand is carried off in a more general and even manner than would be the case if there were only one large opening under the floor. If the latter condition existed, there would be an excess of "draw" and velocity near the waste gate,

but no influence from the waste would be felt by the water at the other side of the canal.

Concerning the operation of these gates the chief engineer of the company states that the ducts do not clog so long as they are operated continuously, but if completely closed for a period, the openings may become clogged with sand and trash and must be cleaned out with a trash hook (shown on top of the check gate in the photograph) before they will start carrying off the sand. He adds that the gates do not remove all of the sand from the canal, but do materially assist in keeping the canal clear.

The complete structure, comprising both the sand and the check gates, contain 135 cubic yards of plain concrete and 95 cubic yards of reinforced concrete. The total cost was $5,388.60, divided as follows, the detail items not being obtainable:

Excavation, concrete work, back filling	$4,160.08
Structural steel for radial gates	953.52
Hoisting device for radial gates	275.00
Total cost	5,388.60

WASTE GATES.

USES OF WASTE GATES.

The waste gate is used on canal systems for two distinct purposes: First, it may be simply a safety valve, carrying off excess water which enters the canal during storms or which is turned back into the canal unexpectedly by consumers. Second, it may be located near the head of the canal with a view of running excess water from the river, relieving the pressure on the headgate in times of flood, and reducing maintenance charges by using the large volume of water to develop a high velocity in the upper reaches of the canal, scouring out sediment. It then becomes a combination of waste and sand gate. In fact, it is very often a hard matter to differentiate between a waste gate and a sand gate. A refinement of the second use is found on systems which are running water to the full capacity of the canal and the rough adjustments at the river gate would allow such fluctuation in the volume in the canal that the banks would be endangered part of the time and the canal not run to capacity at other times. The check below the waste gate on such a system acts as a secondary headgate and the discharge through the check is adjusted to supply the canal to capacity, while excess water is wasted out the gate in the bank adjoining the secondary headgate, the upper headgate being set to discharge more water than would be done if the secondary gate did not exist. The main canal of the Turlock irrigation district (Pl. II, fig. 2, p. 8), and the joint heading spoken of on page 14 are equipped in such a manner.

TYPES OF WASTE GATES.

There are two general types of wastes. The first comprises those acting purely as spillways, having a crest height deemed the controlling elevation of the safe high-water line of the canal. Excess water reaching the waste tops the crest wall and is carried off in a natural watercourse or an auxiliary ditch constructed for the purpose. If the canal is located along a hillside, with no levee on the upper bank, thus allowing surface storm water to come directly into the canal, it is advisable to make the crest wall of such a waste gate of sufficient length that a heavy increase in the water may top the waste and not flow past it. The crest of the above type is sometimes made stationary and sometimes adjustable, being altered by flashboards inserted in slots. Obviously, this type of gate is not adapted to wasting all of the water in the canal. The siphon principle has been successfully used to increase the discharge and decrease the crest length.

The second type of gate has an adjustable opening extending down to or below the grade line of the canal, permitting all of the water to be turned out if necessary. It is quite common practice now to construct such a waste gate with the tops of the shutters below the crest of the side and wing walls so that when the gate is closed completely it still acts as a waste gate of the first type, discharging water from the canal when the water level tops the crest of the shutters. The radial gate is readily adaptable to this form of combination gate, and sand gates operated with radial shutters usually are made so that waste water can top their crests. This is easily done by simply omitting the curtain wall between the piers for a sufficient height to allow of a waste way over the tops of the shutters.

WASTE GATES, YAKIMA PROJECT, UNITED STATES RECLAMATION SERVICE, WASHINGTON.

Plate XI, figure 2, shows an easily adaptable waste way for small laterals or ditches subject to sudden increases of water. Where the ditch crosses a natural drainage way a concrete waterway is set in the levee on the lower side and the levee up and down stream for a short distance is paved with rubble laid in cement. This should have a level crest so that water will top it in an even sheet. Slots are set near the front of the waterway so that flashboards may be set and the general level of the water in the ditch adjusted by them, or they may be " pulled " and all the water wasted. An increase of water which would endanger the ditch or a structure below the waste gate passes completely over the whole structure into the drainage channel.

WASTE GATE, LAKEVIEW IRRIGATION CO. CANAL, WYOMING.

Plate XII, figure 1, shows a small waste gate set in the lower levee of the canal. The crest of the solid wall is set as determined to be the safe or desirable limit for a high-water line in the canal. Excess water within limits, due to storms, passes safely off into the natural drainage way to which the waste is connected. The side walls prevent the erosion and washing out of the bank.

WASTE GATE, TURLOCK IRRIGATION DISTRICT, CALIFORNIA.

The use of very cheaply-built wooden radial gates is brought out in the view of a waste gate shown in Plate XII, figure 2. This gate opens into a short canal with a capacity of 1,000 second-feet. This great discharge is obtained with but three openings. Note that the winches are located only a few inches above the tops of the shutters and that no high gate standards are required. Although the water in the main canal at the time this view was taken was nearly even with the top of the gates, there was absolutely no leakage noticeable at the sides of the shutters, the water in the foreground being either seepage or that remaining from the last run of water through the gate. Note also that this construction provides a crest waste way which will pass off excess water in case the water level in the canal reaches the tops of the gate shutters.

The face of these gates is simple wooden planking, spiked to joists, from which the thrust of the water is carried by wooden arms to a galvanized pipe axle extending completely across the openings. This construction is shown in figure 14, page 50.

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1914